Spatial Analysis of TCM and Western Medical Services in Republican Beijing: An Historical GIS Approach

ZHANG, Peiyao

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Thesis/Assessment Committee

Professor Tsou Jinyeu (Chair)

Professor Lin Hui, Professor Billy K.L. So (Thesis Supervisors)

Professor Huang Bo (Committee Member)

Professor Fan I Chun (External Examiner)

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ABSTRACT

of thesis entitled:

Spatial Analysis of TCM and Western Medical Services in Republican Beijing: An Historical GIS Approach

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This research applies an historical GIS approach, which focuses on the spatial dimension as well as quantitative analysis to explore aspects of TCM and Western medical services in Beijing from 1912 to 1937. This dissertation provides a framework for successful integrated data management by establishing Republican Beijing historical information management as an organizational priority. Based on this framework, a system that integrates the functions of data storage, selective retrieval, analysis, display and archiving is established. First, Republican Beijing historical GIS database is produced. Two approaches are provided to work out the street number sequences and zone the 80 subdistricts respectively. Second, four kinds of spatial analytical methods, including buffer analysis, two-step floating catchment area method, spatial auto-correlation and GWR are integrated and used to explore the spatial patterns of TCM, Western medical services and their correlations with urban morphology, market, religious, educational and legal patterns. The main contributions are three-fold:

First, Republican Beijing historical information management can successfully manage integrated data for medical service studies of Republican Beijing. Historical data coming out of the historical enquiries can be collected, organized, managed, processed, analyzed and displayed. This framework may have some methodological implications on how to collect, organize, represent and analyze historical urban information in a GIS environment.

Second, Republican Beijing historical GIS database is not just the foundation of spatial analysis in this research, but provides a useful resource for scholars in many years to come. Through this database, public health, urban morphology, education, religion, market and legal cultural observations can be accessed by any investigator throughout Republican Beijing. The approach to identifying the street number improves the accuracy of the database while the approach of zoning 80 districts solves the Modifiable Areal Unit Problem. In fact, these are very common problems encountered in historical GIS research that are concerned with "accuracy" and "scale". The two approaches may shed some light on solving such problems.

Finally, through the application of spatial analytical and spatial statistical methods, a better understanding of the spatial patterns of TCM and Western medical services and their correlations with urban morphology, market, religious, educational and legal patterns can be acquired.

摘　要

本研究應用側重於空間維度和定量分析的歷史 GIS 的方法探討了 1912 年至 1937 年期間北京中西醫醫療服務的一些方面。本文通過建立民國北京歷史資訊管理提供了一個有效管理多元歷史城市地理資訊的框架。基於這個框架，建立了一個可集成資料的存儲，查詢，分析，展示和存檔功能的系統。首先，建立了民國北京歷史 GIS 資料庫。分別提供了標識門牌號和劃分 80 個子區域的兩個方法。其次，集成和應用了四種空間分析的方法，包括緩衝區分析，兩步移動搜尋法，空間自相關和地理加權回歸，分析了中西醫醫療服務的空間形態及其與都市形態，教育，宗教，市場和法律形態的互動關係。本文的貢獻主要有三方面：

第一，民國北京歷史資訊管理可以有效地管理用於民國北京醫療服務研究的多元歷史資料。產生於歷史詢問的資料可以被較好地收集，組織，管理，處理，分析和展示。此框架對於如何在 GIS 的環境下有效地獲取、整理、分析、表達歷史城市地理資訊具有某些方法論上的意義。

第二，民國北京歷史 GIS 資料庫不僅是本研究空間分析的基礎，並且為將來的學者提供了有用的資源。任何研究民國北京都市文化的學者都可從此資料庫中獲取關於公共衛生，都市形態，教育，宗教，市場和法律等文化層面的相關資料。標識門牌號的方法改進了資料庫的精度，而劃分 80 個分區的方法則解

決了 MUAP 問題。事實上，這是歷史 GIS 研究中常見的兩個關於精度和尺度的問題。這兩個方法可以為解決此類問題提供借鑒。

第三，通過空間分析和空間統計方法的應用，可以獲得對民國北京的中西醫醫療服務的空間形態及其與都市形態，教育，宗教，市場和法律形態的互動關係的更好的理解。

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ABBREVIATIONS

GIS	Geographic Information System
TCM	Traditional Chinese Medicine
MAUP	Modifiable Areal Unit Problem
Two-SFCA	Two Step Floating Catchment Area
GWR	Geographically Weighted Regression
PUMC	Peking Union Medical College
CHGIS	Chinese historical GIS
GBHGIS	Great Britain Historical GIS
NHGIS	National Historical GIS
MSJGIS	Ming Song Jiang GIS
CCTS	Chinese Civilization in Time and Space
ESRI	Environmental System Research Institute
ISO	International Organization for Standardization
OLR	Ordinary Linear Regression
OLS	Ordinary Least Squares

CHAPTER 1: INTRODUCTION

1.1 Research Background

The impact of medicine and disease to humanity is immense and multi-dimensional. On the one hand, disease can be seen as purely a biological event, causing pain and damage to the human body. On the other, it can also be seen as a complex social event. Its impact ranges from influence on reproduction, to changes on the development of human civilization (Zhang 2006). As a matter of fact, there was a long period of time when, the socio-cultural value of historical research on medicine and disease was largely neglected. In the 1970s, under the influence of the new historical theorists like the Annales School, the western medical research shifted focus to the socio-cultural research on disease and medicine. At the same time, historians also began their research on the socio-cultural history of disease. Nowadays, social history of medicine is among the hottest topics of the historiography of medicine worldwide. Yet, the study in China is still at its early stage, and hence it is of great significance to begin research on the social history of medicine and disease in modern day China.

Republican Beijing refers to Beijing city from the fall the Manchu empire to the fall of the city into the hands of the Japanese army, i.e., 1912 — 1937. Beijing was renamed as Beiping during the period between 1928 — 1949 when the Nationalist government relocated the nation's capital to Nanjing. There are three reasons for choosing Republican Beijing to be the study area: First, as Republican

Beijing was no longer the national capital since 1927, the city was only a city in transition and thus its historical status was largely neglected at that time. Regarding modern Chinese urban historical studies, Beijing received very little attention, whereas a great deal of scholarly attention was put on Shanghai instead. As Beijing has had a long history and is referred as "traditional city", there is great potential for research on the historical geography of China. Second, republican Beijing was a place where the greatest conflict between Chinese and Western culture took place. Concerning medical and health culture, Western medicine experienced rapid change in Beijing, and the new framework of medical and health service system was established during this period. This indicates not only the richness of the research materials, but also reveals the fact that such research is highly representative. Third, as the former capital, the development of Beijing, to some extent, foreshadowed the direction of the nation's development. Therefore, a more comprehensive and in-depth research on the medical and health culture of republican Beijing would definitely yield a better understanding of the social development of modern China.

As the medical history of modern China covers not only the introduction of Western science and technology into China, but also has a close relationship with the local community, it provides another possible perspective to re-examine development issues in modern Chinese society (Leung 2007). Since modern times, both colony and semi - colonies had attempted to manipulate and learn from the scientific medical resources of the colonizers as a means to resist the control of the western countries. Medicine became a tool for self-defense and development for nationalists in the late 19th and early 20th century (Zhao 1989). Such a perspective emphasizes the complex mentality of the colonial intellectual elites, in the process of imitation and wrestling, but simplifies the screening and adaption process as the resources from the West entered the local cultural system. The introduction of western medical technology and its system was not a one-way process, as the traditional Chinese society did not accept everything reluctantly. The modernization of China was a process of struggle and blending between "modernity" and "tradition". The study of the medical history of republican Beijing aids the understandings and shaping of the social changes of contemporary China, as well as further revealing the unique features of China's modernization.

Historical geography is the study of the geographies of past times, involving the imaginative reconstruction of a wide range of phenomena and processes central to our understanding of the dynamism of human affairs. For example, changes in the evaluation and uses of human and natural resources, in the form and functions of human settlements and built environments, in the advances, in the amounts and forms of geographic knowledge and in the exercising of power and control over territories and people (Butlin 1993). The term 'historical geography' has come to be increasingly identified with an approach in which the data are historical but in which the method is geographical. The purpose of the historical geographer, according to this view, is to reconstruct the geography of the past (Darby 1953).

In more traditional scholarship, Chinese historical geography was usually studied by combining the analysis of historical materials with on-site inspection due to technological limitations (Hou 1993; Li 2003). This qualitative method was effective in reconstructing a horizontal cross section in history and studying related sectional issues but inadequate in analyzing the rule of transition through synchronic and diachronic comparison (Li 2000). Consequently, there is room to promote historio-geographic studies by employing new measures and methods.

Historical urban geography is a subdivision of historical geography. Its focus is on cities in different historical periods, including the study of the rise, the development and the changes of a city (Yan 2003). The characteristics of historical urban geographic information can be summarized into regionality, integrity and time-sequence.

Regionality. "Region" refers to the space on the surface of the earth. So "regionality" follows the principle that the study of cities in all historical periods should fall on the space above the earth surface. The study of historical urban geography is the relationship between the characteristics of city space and the geographical environment of such space. Regionality exists both in the region where the city locates and within the city itself.

Integrity. In historical urban geography, all factors that affect the city development of a particular historical period should be taken into consideration for integrated research. The climate, geomorphology, hydrology, biology and soil, for example, of a city are important natural elements that influence the formation of socio-economic features of a city, such as population and economic development. On the other hand, the socio-economic development has great impact with respect to the changes of the natural geographical elements of a city. Hence, natural geographical factors and human factors are interrelated to each other.

Time-sequence. The study of historical urban geography requires the integration of the history, present situation and the development of the city, the reconstruction and comparison of historical periods, to fully reveal the rule of urban development of historical periods. Spatio-temporal analysis is the fundamental analytical method.

Using "geographic information" to study geographical objects and geographical phenomena is one of the most important methods in modern geography. The scientific method of geographic information refers to the notion, method and means adopted to explore the properties of geographical objects and principles of geographical phenomena, which converts the physical world to the spiritual world. The followings are the commonly used methods and ways of presentation in geographic information science:

- The mode of direct/indirect perception and interpretation of graphics and images.

- The mode of applied mathematics function/formulae.

- Mode of massified image-numeric-rationality.
- The reasoning of semi-structural/non-structural geographic information.
- The method of applying computer technology into analogy and simulation.
- Combined mode of the above methods.

The widespread application of GIS (geographical information system) in recent decades has increasing impacts on the approaches available to the students of historical geography, history and Chinese studies (Bol and Ge 2005; Knowles 2002; Gregory et al 2007). GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. As an information system dealing with the spatial relationships among different geographical features, GIS makes it possible to analyze spatial changes over time by using the computer. The combination of GIS and historical geography (i.e. Historical GIS) has become an increasingly promising area of research, in the context of Chinese history, even though actual empirical cases of application remain limited. There are at least three advantages of using GIS in historical geographical studies, in particular in historical urban studies: First, GIS is able to integrate large amount of data of multiple variables from many sources. Second, quantitative analysis can be conducted by using spatial analysis and spatial statistics. Third, the visualization tools of GIS may inspire new enquiries. The present research thus attempts to investigate the Traditional Chinese Medicine (TCM) and Western medical services in Republican Beijing by using GIS.

1.2 Research Questions

The research questions arise from the process of applying GIS to Beijing medical historical studies. The process includes two components: historical data management and data analysis, and the former is the foundation for the latter. The research purpose is to provide a framework to manage Beijing medical historical data efficiently. The features of Beijing medical historical data make the data management a challenge. There are two research questions that can be identified. One is how to collect, organize, manage and represent historical data and the other is how to process and analyze historical data. The first question mainly concerns the representation of historical data in a GIS environment, and the second question mainly concerns the selection and application of appropriate spatial analytical methods in terms of research enquiries.

The data in the present research are collected according to six cultural spheres: public health cultures, urban morphology, market cultures, education cultures, legal cultures, and religious cultures. The richness and diversity of the data on multi-cultural spheres will require the implementation of more powerful data management and analytical techniques. The cost of acquiring historical data alone justifies the development of dedicated systems for integration of these data. Not only do a wide variety of data sources need to be handled, but myriads of data structures as well. This requires that the large amount of information that will accrue be intelligently catalogued and spatially and temporally co-registered. The present research has therefore established Republican Beijing historical information management as an organizational priority.

For ordinary GIS projects, data acquisition or capture usually requires the most effort. During this process, data quality is occasionally a major concern. But for most historical GIS projects, these two related issues are of disproportional significance (Wong et al. 2010). Acquiring relevant historical geospatial data is challenging by itself. Quality of the historical geospatial data complicates the data acquisition process significantly. Not only historical geospatial are sparse in general, their quality may not be at the preferred level. Quite often, the issue is reduced to the trade-off between acquiring less than desirable quality data versus not having any data at all. While gathering imperfect data may be the norm, the present research has demonstrated how spatial analytical techniques in GIS may be able to enhance the quality of historical GIS data so that they can support the intended analyses.

In the analysis of TCM and Western medical services in Republican Beijing, we attempt a) to reveal the spatial patterns of TCM and Western medical services over time; b) to explore the relationships between medical services and urban traffic; c) to explore the correlations between medical services and various variables. The spatial analytical techniques should be selected according to the research enquiries. As the data collected are also spatial data, the characteristics of spatial data, such as spatial autocorrelation and spatial non-stationarity, need to be considered as well. In addition, the characteristics of historical data usually limit the application of spatial analysis and spatial statistics. For instance, the "non-homogeneity" over time and space might be a problem when conducting spatial-temporal analysis. Therefore, the data needs to be further processed for the application of selected spatial analytical methods.

In conclusion, the Beijing medical historical data can be characterized as diverse, complicated, inaccurate, sparse and non-homogeneous. These features make it a challenge to collect, manage, represent and analyze these data to answer historical enquiries in a GIS environment.

1.3 Study Area

Beijing is situated at the northern tip of the roughly triangular North China Plain, which opens to the south and east of the city (see fig.1.1). Mountains to the north, northwest and west shield the city and northern China's agricultural heartland from the encroaching desert steppes. To the south and east of the city stretches a flat, level, coastal plain, built up by the Pai Ho (White River) and the Huang Ho (Yellow River), the two chief rivers of North china. To the north and west of the city, the land rises rapidly, so that within 15 miles on the west and 25 miles on the north are hills 2600 feet high, while 35 miles to the northwest is the Great Wall of China, built on terrain over 4000 feet high.

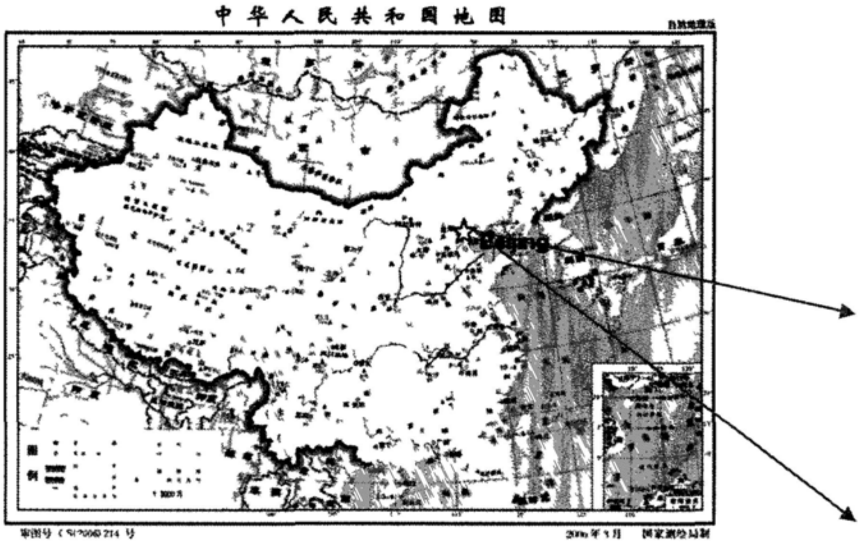


Fig. 1.1 Geographical location of Beijing

Beijing city includes North City and South City. For the purpose of police administration, Beijing was divided into 20 police districts in 1912, which were restructured into 11 police districts from 1928. As far as the 20 districts are concerned, the Central Districts are in the imperial city, but do not include the Forbidden City, which is special government property, not open to the general public and not part of the area under the direct supervision of the police. The Inside Districts are in the North City and the Outside Districts are in the south city. The Left Districts are on the east, and the Right Districts on the west side of the city. Fig.1.2 shows the 20 police districts of Republican Beijing.

The main thoroughfares of Beijing city had been laid out during imperial times. There were a great majority of highways built in the North City. All nine of the gates of the North City have these highways, running to them and there are four roads running across the city from north to south and four from east to west. In the South city, there are only two main highways. One connected the center gates in the north and south walls while the other joined the center gates in the east and west walls (Gamble 1921).

The urban traffic was in a poor condition until the early years of the Republic. A great deal of work on street construction and maintenance had been carried out and great improvement made. By 1937, there were hundreds of miles of roads built with asphalt, concrete and macadam. These well-paved roads constituted the main transport network of the city.

The streetcar system, which served as the public transport, developed as the streets were opened up and widened. Streetcars provided faster access between areas than the old-style vehicles and further integrated Beijing's cellular neighbourhoods. By 1937, the streetcar system had covered the whole city, making it a more convenient and faster travel across the city. Another important means of transportation were rickshaws. The rickshaws could be found almost anywhere in the city, day or night and could be engaged for a short or long run. The charge was relatively cheap and usually fixed depending on factors like, for example, the length of the run, the time of the day, the weather, the number of rickshaws around and how far from his regular stand the coolie was to be dismissed.

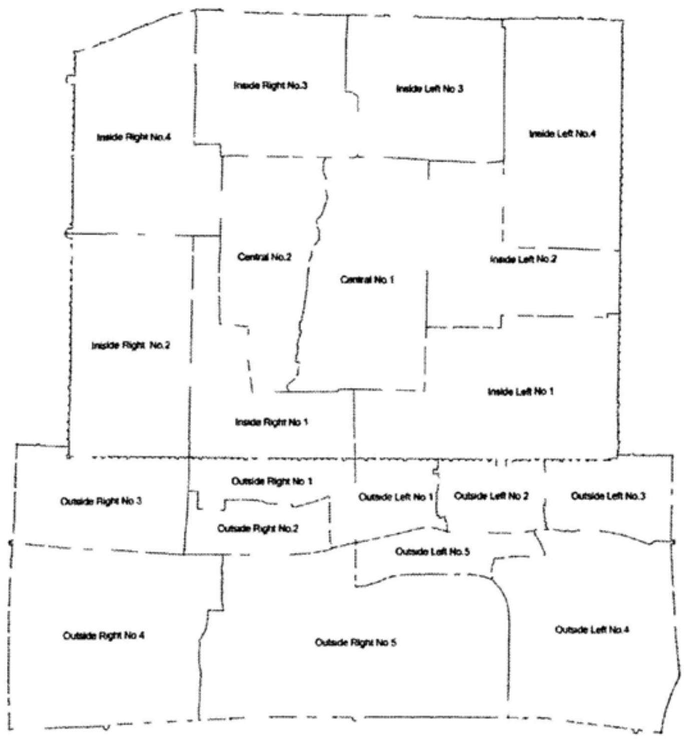


Fig. 1.2: 20 police districts of Republican Beijing

1.4 Research Objective and Significance

The object of observation in this study is the spatial phenomena of TCM and Western medical services in a Beijing liberated from the dominating imperial ideological control. The main theme of inquiry is how much medical service changes over time can be systematically observed in spatial patterns and be further elucidated through spatial analysis.

The significance of this study is that a framework that successfully manages integrated data for medical service studies in Republican Beijing will be provided. One of the most important outcomes of this framework will be a Beijing medical historical GIS database. This database will further enable the application of spatial analysis to explore the spatial patterns of medical services and their correlations with other variables. It will be the first attempt to apply spatial analysis and spatial statistics to Beijing medical historical studies. It promises to reveal the spatial patterns of TCM and Western medical services and their correlations.

The significance of this study also lies in the diversity and richness of information and will be systematically incorporated into a conceptual framework of analysis. Such a task becomes possible through the application of the GIS technique. It will be the first attempt to collect and process such information about Beijing in a medical historical context. A better understanding of the spatial patterns of TCM and Western medical services and their correlations with a wide range of variables will be acquired through the application of spatial analysis and spatial statistics based on GIS.

The main objectives are

a) To establish Beijing medical historical information management;
b) To produce Beijing medical historical GIS database;
c) To reveal the spatial patterns of TCM and Western medical services over time by using spatial autocorrelation;
d) To explore the relationships between medical services and urban traffic by using buffer analysis and hotspot analysis;
e) To explore the relationships between medical services and a wide range of variables by using GWR.

1.5 Structure of the Dissertation

The dissertation consists of six parts: the introduction, review, methodology, database, spatial data analysis and conclusion, in total eight chapters. The first chapter is the introduction, in which the research background, research questions, study area, research significance and objectives have been introduced.

Chapter Two constitutes the review. In this chapter, some basic historical approaches to studying medical and health culture in Republican Beijing are introduced and the development of historical GIS is reviewed.

Chapter Three constitutes the methodologies. This chapter addresses the first research objective: to provide a framework for integrated data management. The Republican Beijing historical information management is established as an organizational priority. The choice of the spatial analytical methods integrated in the framework and their methodologies are introduced as well.

Chapter Four constitutes the database. This chapter addresses the second research objective: to build the Republican Beijing historical GIS database. The procedure of building the database and the problems encountered are described. This chapter provides two approaches to improving the accuracy of the database and solving Modifiable Areal Unit Problem (MAUP).

The spatial data analysis section constitutes chapters Five, Six and Seven. These chapters addresses the last three research objectives, to reveal the spatial patterns of medical services and their interplay with a wide range of variables by using spatial analysis. In chapter Five, Moran's I statistics and hotspot analysis are used to analyze the global and local spatial autocorrelation of TCM and Western medical services in the 1910s, 1920s and 1930s. In chapter Six, buffer analysis and two step floating catchment area (two-SFCA) method are used to explore the spatial patterns of TCM and Western medical services and their relationships with the urban traffic in the 1930s. In chapter Seven, Geographically Weighted regression (GWR) is used to analyze the spatial non-stationarity of the relationships between medical services and other factors such as population, temples, churches, industry-commerce, taps, lawyers and schools in the 1930s.

Chapter Eight constitutes the conclusion. First, this chapter summarizes the present research. Second, the contributions of the present research are presented. Finally, limitations of the present research and future directions are presented.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews some fields related to this study. In section 2, we will present the historical approaches used for Beijing medical and health cultural studies. Section 3 presents the development of historical GIS at home and abroad. The last section is a summary of this chapter.

2.2 Medical and Health Culture in Republican Beijing

For most modern scholarship on Medical and health culture in Republican Beijing over the past two decades, there are at least four identifiable approaches: Gamble's Peking health culture, "PUMC study" Medical and Health history approach, Sherman Cochran's business history approach and New Medical and Health cultural history.

2.2.1 Gamble's Peking health culture

Gamble (1921) gave a whole chapter to the Beijing health conditions in his book, '*Peking: a social survey*'. According to Gamble, the Beijing health and medical urban administration was run by the Police, the Board of Health being one of the departments of the Police Board. A large number of health ordinances were adopted by the Board of Health and great progress had been made in the sanitation of the city. He pointed out that the statistics on birth and death rates conducted by the police were inaccurate due to the fact that people would not report all births and deaths. Based on the statistics, one could have a rough impression of the low birth rate and high female death rate. One encouraging thing is that there was a remarkable decrease in the number of outbreaks of epidemic disease in the early republican period. Gamble also looked into the development of hospitals and medical schools in Republican Bejing. He noted that there was an increase in the numbers of hospitals as well as medical schools and the government had begun to be engaged in medical education.

In Gamble's book, he touched on those important aspects of public health in Republican Beijing. However, his main concern was centered on the city's public hygiene improvement.

2.2.2 "PUMC study" Medical and Health history approach

Among the modern hospitals opened in Beijing in the 1910's the most influential and famous must be the Peking Union Medical College (PUMC) funded by the Rockefeller Foundation. The hospital has undergone many changes and closures over the past century but is now still one of the most important ones in Beijing. The Rockefeller Archive Center in Tarrytown, New York preserves a very good archive of the PUMC and has supported many publications pertaining to PUMC, the bibliography of which runs into a few hundred pages. It is a representative scholarship of the medical modernization history of China, in particular that of Beijing. The underlying approach is the introduction of western medicine into Beijing as represented by the medical and health service that embodied the medical and health culture of Western society in the early 20th century.

All of the Western scholars spoke highly of the work done in China by the Rockefeller foundation and its China Medical Board: "None of these organizations made so large a contribution, nor has exerted so profound an influence in the setting of modern standards, as has been effected by the Rockefeller Foundation of New York." (Balme 1921) "In creating the Peking Union Medical College we were far wiser than we realized. The concept of modern medicine which was introduced there set in motion influence in China that can not be stopped. The conflict of ideologies - what Gibbon called "the exquisite rancor of theological hatred" – does not relate to medicine, for health is something that all men desire, and there is no limited supply for which nations must compete. Modern medicine is one of the ties that bind the human race together regardless of ideologies and boundary lines. It is one of the rallying points of unity and is thus a foundation stone in the ultimate structure of a united society." (Ferguson 1970)

Recently, Chinese scholar Zhang Daqing (2009) examined in great detail the surveys on health-care medicine in China by the China Medical Commission of the Rockefeller Foundation and its effect on medical education and health care in China. He has found that the surveys allowed the possibility of a Chinese medical project, but also provided a lot of information for the American medical establishment to understand the situation of health care and medical education in China. He has emphasized that the point that the Chinese medical project of the Rockefeller Foundation played an important role in the mapping of modern medicine in China.

2.2.3 Cochran's business history approach

The eminent business historian Sherman Cochran has given the Beijing medical history yet another new dimension. He treated medical history as business history. In his recent book on Chinese Medicine Men (2006), he studied the corporate histories of a number of Chinese business families that engaged in Traditional Chinese Medicine. His Beijing example is the Tongren tang of the Yue's family. The TCM Store has been established for a few hundred years and is very famous in Beijing. It is a history of how Traditional Chinese Medicine as a commodity is packaged using Western marketing skills but preserving a genuine Chinese tradition. Chinese entrepreneurs selling Western-style drugs exploited the new media, such as posters, calendars and newspapers, to advertise nationwide and to control nationwide distribution. In contrast, the Chinese entrepreneurs selling Traditional Chinese Medicines tended not to make use of those media during he nineteenth century and early twentieth century. In Cochran's view, the traditional Chinese drug stores played an important role in consumer cultures as the Western-style drugstores did at that time. They also pushed out the frontiers of long distance trade, evaded political barriers, carried out localization and contributed to homogenization.

2.2.4 New Medical and Health cultural history

There is an active research agenda on the medical and health culture during the 20th century from a cultural history perspective that takes into account the wide range of social, political, legal, economical and religious factors behind the interplay between Western medicine and Traditional Chinese medicine that created the hybrid medical and health culture in Chinese communities today (Yu 2003; Leung 2007).

These studies highlighted the struggle between the two contrasting traditions. Some are interested in studying the medical aspect of Chinese state building rightly place the state as the central actor and investigated the consequences of its various medical policies. These include Anelissa Luca's Chinese medical modernization (1982), Ka-che Yip's Health and National Reconstruction in Nationalist China – development of modern health services, 1928 – 1937 (1996). On the other hand, some scholars studying the struggle between Chinese and Western-style doctors have seen the simultaneous emergence of the sate as having had little to do with the course of the medical struggle. This view is represented by Ralph Croizier's "*Traditional Medicine in Modern China: Science, Nationalism, and the Tension of Cultural Change*" (1968) and Zhao Hongjun's "*Jindai Zhongxiyi Lunzhengshi [Chinese versus Western Medicine: a history of their relationships in the twentieth century]*" (1989). In addition, there are some others who argued that the construction of the modern state medical infrastructure and the struggle between Western medicine and Traditional Chinese medicine were two processes intertwined rather than separate. Bridie Andrew's dissertation, "*The Making of Modern Chinese Medicine,* *1895-1937*" (1996) and Hslang-Lin Lei's dissertation, "*When Chinese Medicine encountered the state: 1910-1949*" (1999) are two excellent examples. Hslang-Lin Lei investigated in great detail the conflict and struggle between Western medicine and Traditional Chinese Medicine and their relationships with the state. From his point of view, the Chinese doctors adopted the strategy of assimilating Chinese medicine into the emerging national medical system, their efforts radically transformed the theories, practice and social network of Chinese medicine. The Traditional Chinese medicine began to be re-constructed at the moment when Chinese medicine encountered the state.

In traditional scholarship, Chinese medical history was usually studied by combining the analysis of historical materials with on-site inspection. This qualitative method was effective in reconstructing the history and studying related issues. However, there were some limitations: a) The focus was more on the temporal dimension than the spatial one. b) More was done on qualitative than quantitative analysis. c) There was more detailed research on department analysis than integrated analysis. Consequently, there is an opportunity to promote medical historical studies by employing new measures and methods.

2.3 Historical GIS

The increasing application of GIS (geographical information system) in recent decades has had a striking impact on the approaches available to historical geographers. The combination of GIS and historical studies (i.e. Historical GIS), has become an increasingly attractive area of research. Significant progress has been made in the development of historical GIS.

2.3.1 Database development

One focus has been the emphasis on building national historical GISs. CHGIS (The Chinese historical GIS) (Berman 2005; Bol and Ge 2005) launched by Harvard and Fudan Universities established a database of populated places and historical administrative units for the course of Chinese history between 222 B.C.E. and 1911 C.E. It serves as an historical gazetteer to provide basic information of place-names. This system is an open-ended platform for further expansion and usage. They applied commonly used GIS standard formats (i.e. ESRI shape files and MapInfo formats). It is very useful for researchers to work on the historical change of administrative units and create historical maps for specific time periods.

GBHGIS (Great Britain Historical GIS) (Gregory et al. 2002) contains the evolving boundaries of all the major administrative and statistical reporting areas of Great Britain. This holds data on census, registration and Poor Law from the early nineteenth century to the 1970s. The core of the system is a GIS database that holds the major administrative units as they changed between 1840 and 1973.

NHGIS (National Historical GIS) (Fitch and Ruggles 2003; McMaster and Noble 2005) incorporates all available aggregate census information between 1790 and 2000 for the United States. CCTS (Chinese civilization in time and space) by Academia Sinica constructs an integrated GIS-based application infrastructure within the spatial extent of China, in the timeframe of Chinese history, and with the contents of Chinese civilization (2002). Other national historical GISs include the German historical GIS (Andreas 2005), Russian historical GIS (Merzlyakova 2005), Belgium historical GIS (De Moor and Wiedemann 2001) and South Korea historical GIS (Kim 2005). Most of them consist of large amounts of digitised historical maps and related statistical data on the socio-economy during the historical period.

Another application of GIS to historical studies is focused on urban development. DeBats and Lethbridge (2005) have studied the residential patterns of Alexandria, VA and Newport Kentuchy between 1859-1874, using combined information from census, local directories, municipal election and electoral records, city tax records and church congregation membership lists, to build a GIS database of 28,000 individual residents with attributes including their voting choices. Their project aims at examining the relationship between residential patterns and political behaviors in voting, an indicator of political culture. Their paper is an attempt to seek a linkage between culture and class through GIS and enables a detailed examination of the interplay between individual political culture and observable spatial patterns of these individual residents.

Siebert (2000) has done a historical GIS project of Tokyo from the mid-19th century to the present, using data on physical landscape, administrative boundaries, population, economic census, commercial and industrial activities, growth of road and rail networks, land ownership and so on to produce a temporal GIS for Tokyo.

The main purpose is to capture the spatial patterns of these variables. Her urban history of Tokyo takes into account the changes in urban landscape and demography. Her works are useful for urban planning but seem not to have developed into historical research.

So (2006), has developed a MingSongJiangGIS (MSJGIS), which is a micro database of historical GIS on the spatial structure of the cotton textile industry of late Ming Songjiangfu. It identifies the location of towns and cities, and attempts to draw the boundaries of the sub-county administrative units (e.g.Bao), with reference to the data of location of temples and schools, as well as trade routes, topology, for example.

There are more examples. The Sydney GIS (Wilson 2001) has been focused on museum artefacts and locating these in space by complementing them with a series of maps of the city from the very early days of European settlement to the present. Kyoto Virtual Time-Space has provided a platform through which various other digital archives can be utilized. However, both of them are developed to reconstruct the urban landscape and historical remains for different periods.

2.3.2 Application of Spatial Analysis to Historical Studies

Based on these accessible historical GIS, some scholars have started to analyze historical issues by employing spatial analytic method. Hillier (2002; 2003) has applied spatial analysis, including spatial regression, hotspot analysis to studying the "mortgage redlining" in the city of Philadelphia. The results suggested that areas with high African American populations were more likely to be red-lined than other areas, but contradict the orthodoxy that once an area was red-lined it was difficult to get a mortgage.

Knowles and Healey (2006) have conducted a spatiotemporal analysis based on GIS to re-examine the development of Pennsylvania's iron industry in the mid-nineteenth century. They have tested hypotheses on the timing of adoption of fossil-fuel technologies across the state, the temporal relationships between investment in ironworks, business cycles, and tariff policy, different types and qualities of iron and how transport costs affected iron prices and the geographical segmentation of iron markets. The results suggested complex and dynamic patterns of regional economic development.

Zhang et al. (2007) have used spatial analysis as well as spatial statistics to demonstrate the distribution and change of population during the Ming and Qing periods in terms of the spatial structure and institutional matrix in the Songjiangfu region. They have demonstrated the characteristics of population distribution and how those patterns changed over time. The analytical results suggested the effects of massacre are one of the major driving forces for the population loss during the Ming-Qing transition and the economic factors are closely correlated to the rapid population growth in Songjiangfu.

Gregory et al. (2001) have found that area interpolation can be a useful tool for historical studies. They have analyzed the changing patterns of poverty in England

and Wales through the twentieth century by comparing key quantitative indicators by using this method. The comparison became possible by interpolating all the datasets onto a single standard geography. They have shown the inequality between the areas containing best and worst off population deciles appears to have risen during the twentieth century.

All in all, historical GIS has been developed rapidly abroad in the past decade. However, the application of GIS to Chinese historical studies is still at an early stage of development. There has not been an historical GIS developed for Beijing medical historical studies.

2.4 Summary

We have reviewed the historical approaches used for medical and health cultural studies in Republican Beijing and the development of historical GIS. In more traditional scholarship, Beijing medical and health cultures were usually studied through the analysis of historical materials. They seldom used quantitative methods or new technologies. On the other hand, historical GIS has been developed rapidly in the past decade, but few studies have been applied to Chinese history. There has not been an historical GIS developed for Beijing medical historical studies.

CHAPTER 3: RESEARCH FRAMEWORK AND METHODOLOGY

3.1 Introduction

This chapter will provide a framework for successful integrated data management for medical service studies in Republican Beijing. In section 2, we will present the Republican Beijing historical information management. Section 3 presents the procedure and requirements for building the Republican Beijing historical GIS database. Section 4 presents our choices of spatial analytical and statistical methods in terms of research aims. The last section is a summary of this chapter.

3.2 Research Framework

Fig.3.1 presents an overall framework for this research and it includes four phases: data preparation, data modeling, database development, and data analysis.

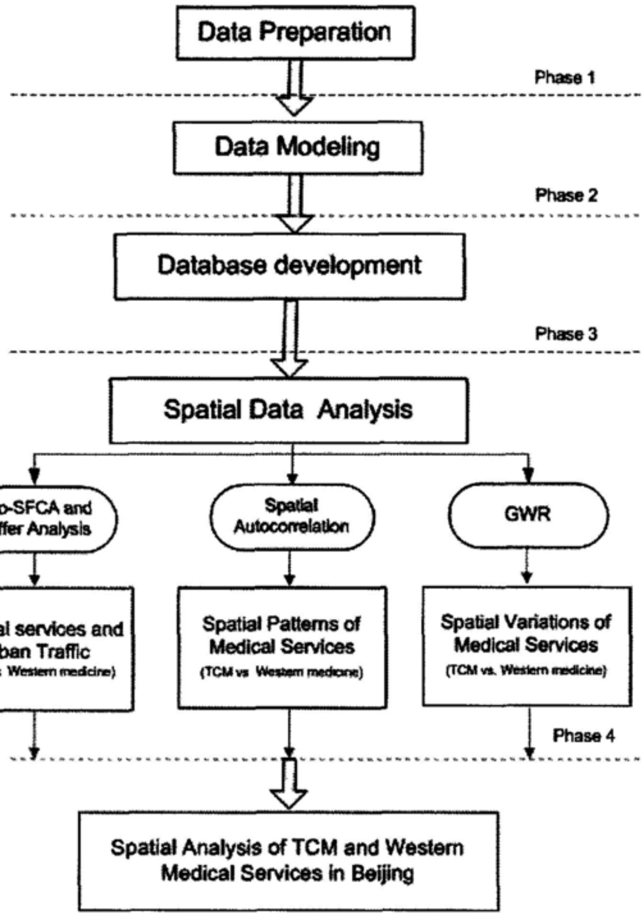


Fig. 3.1 A Framework for Analyzing Medical Services in Republican Beijing

3.2.1 Formulation of Republican Beijing historical GIS

The formulation of the Republican Beijing historical GIS emphasizes the management of historical information and derives from the acquisition systems. This better reflects the information requirements of the historians and thus helps us gain a better understanding of the historical enquiries addressed. The information is generalized according to six cultural spheres: public health cultures, urban morphology, market cultures, education cultures, legal cultures and religious cultures. These six cultural spheres are selected due to the fact that: a) The data is relatively accessible. b) Each sphere represents an important aspect of the urban cultural transformation. c) There is potential interrelatedness between medical cultures and other cultural spheres. For example, Western medicine and education were introduced through the work of missionaries; new legal frameworks and municipal administration reform based on Western models affected market institutions, behaviors and performance; urban morphology changed following new approaches to health care, law and order, education, and changes in religious beliefs, and so on. Figure 2 describes the main functions of each cultural sphere. The data supporting these functions are identified in table 1.

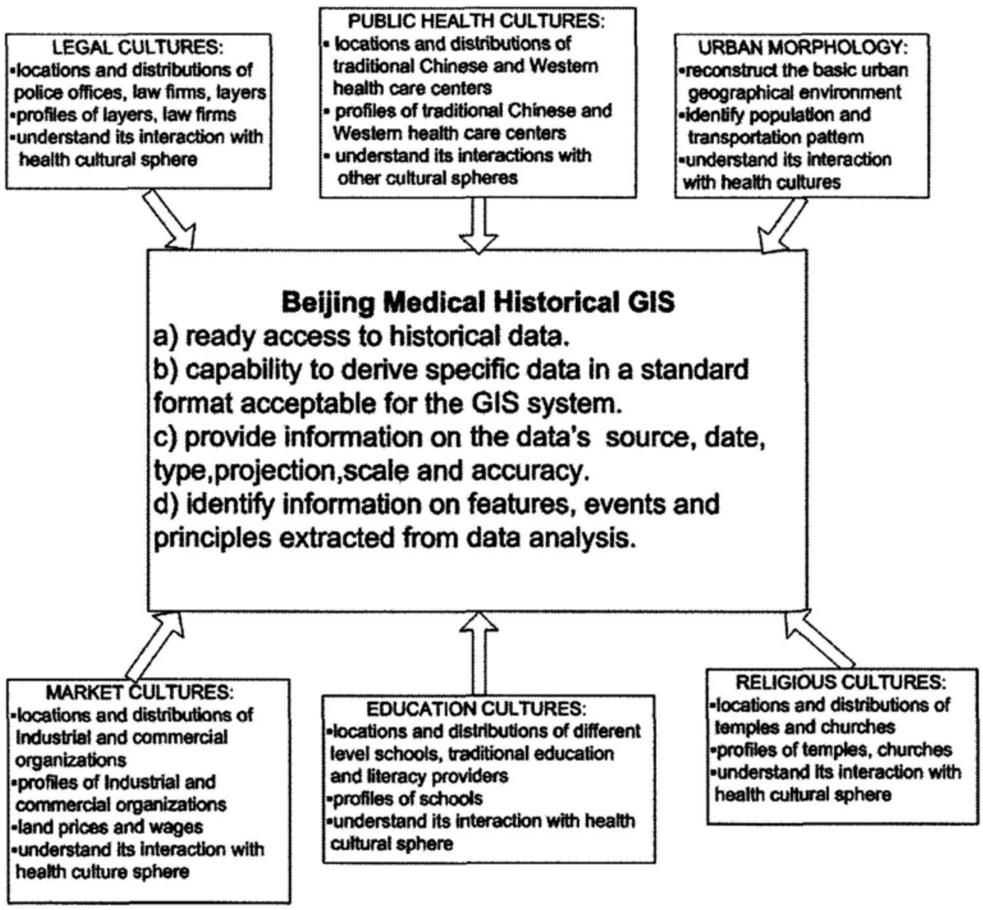


Fig. 3.2. Organizational function diagram for Republican Beijing historical GIS

Table 3.1 Six Cultural spheres and their contents

Cultural sphere	Data

Public health cultures	Traditional health care providers, modern hospitals and clinics, public health services, Chinese and western drugstores, patterns of common and infectious diseases, hygienic facilities,…
Urban morphology	City planning and structure, major government buildings, major landmarks, urban population patterns, and transportation patterns,…
Market cultures	Firms and shops of major businesses, banking and pawn brokers, manufacturing enterprises, guilds, temple markets, urban taxation, land price, wage patterns, poverty patterns,…
Education cultures	Schools, universities, professional education organizations, traditional education providers, literacy providers,…
Legal cultures	Police forces, military police, crime rates, medication, court systems, civil and criminal litigations, lawyers and law firms…
Religious cultures	Temples, churches, properties, membership, leadership, welfare services …

3.2.2 Republican Beijing historical information management

Republican Beijing historical information management includes three parts: data collection, data management and data analysis (See figure 3).

Raw data is collected through an investigation of historical materials and on-site inspection. Most of the information is available in archives and libraries in Beijing. These are maps, official census, reports, statistics, registries, and private surveys, reports, guidebooks, books and other publications. All of this data needs to be classified in terms of the six cultural spheres and prepared in a format accepted by the GIS system.

Database management is focused on providing integrated management of the historical data which will be accessed in numerous ways by a variety of users. The entities are thus very much constrained by the data model of the chosen GIS. We use the geodatabase data model developed by ESRI (2010). The geodatabase is the common data storage and management framework for ArcGIS. It combines "geo" (spatial data) with "database" (data repository) to create a central data repository for spatial data storage and management. The data in this part are vector data stored in the geodatabase as thematic layers called feature classes (See fig.3). A feature class is a collection of geographic features with the same geometry type, such as a point, line, or polygon; the same attributes; and the same coordinate system. Feature classes can be grouped together within a feature dataset—a collection of feature classes—to model geospatial relationships between them. By storing feature classes within a feature dataset, geospatial relationships such as topology and network dataset can be modeled between the feature classes, enabling more advanced GIS analysis. In fig.3, the associated attributes for each feature class and its spatial relationships with other features are listed below.

Data analysis is focused on how historians derive meaning and knowledge from the data by using spatial analysis based on GIS. This framework integrates four kinds of spatial analytical methods for analyzing traditional Chinese and Western medical services in Beijing: two-SFCA method, buffer analysis, spatial autocorrelation and geographically weighted regression (GWR). These methods will be introduced in detail in the next section. All of the analytical results can be displayed by using GIS visualization tools. Historians are then able to view, query, summarize and make decisions based on the GIS platform. In this way, new knowledge may be gained and new hypotheses can be tested. This circle of activity will finally return to the data collection.

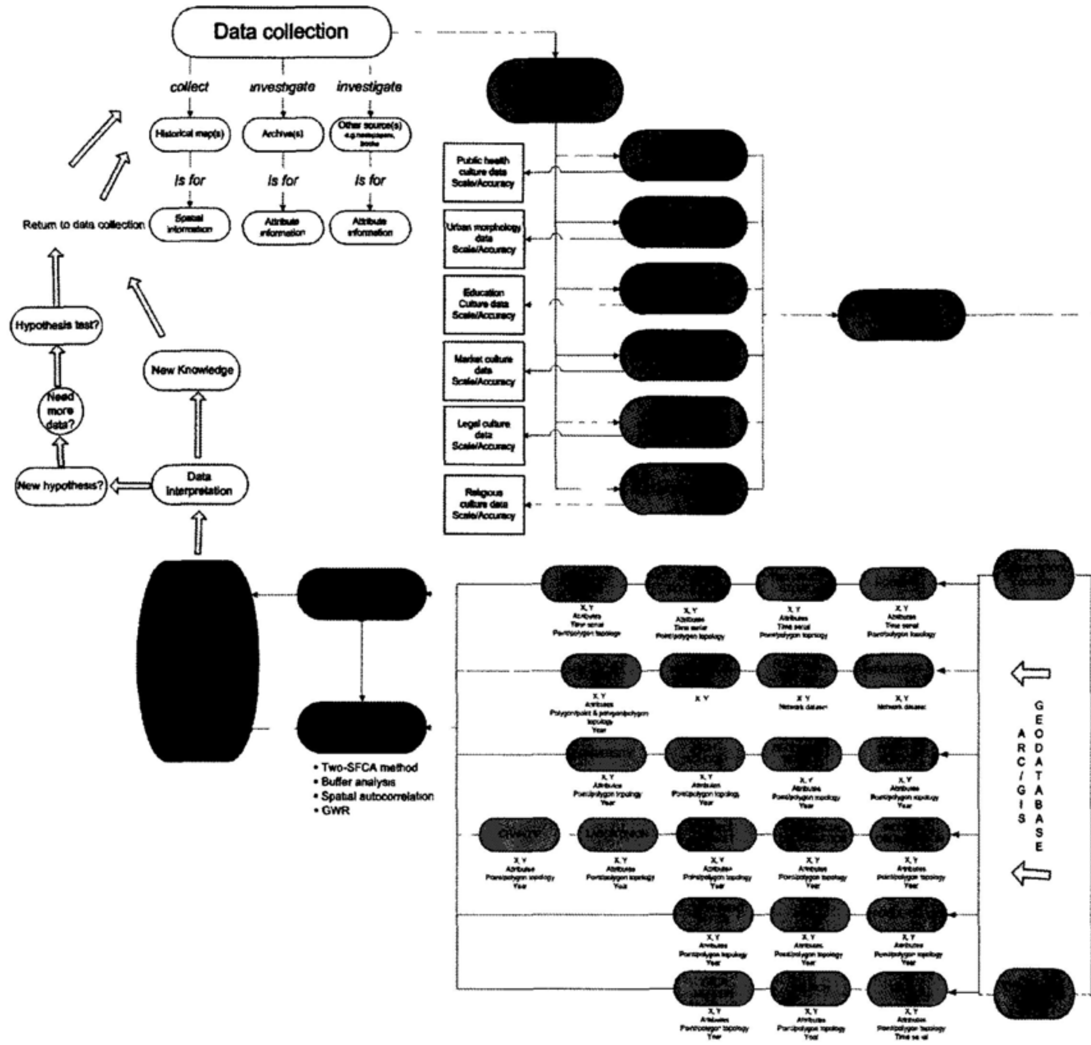


Fig. 3.3 Republican Beijing historical information management

3.3 Database

A historical GIS database will be built according to the Republican Beijing historical data management. There are three steps included in this procedure (see figure 4). The first step is to collect historical data, including spatial data and attribute data. A serial of historical maps are required to create a high resolution base map as the foundation of spatial data. These maps need to be geo-referenced to make them conform to the same spatial reference system and the most detailed map should be digitized. The second step is to process historical data and control the quality of the data. Historical sources are frequently incomplete, inaccurate and ambiguous. The "error" or "uncertainty" problems with historical GIS are not necessarily with sources but are sometimes also caused by the limitations of GIS. Such problems can be solved by combining GIS techniques and traditional historical approaches handling historical data. The last step is to classify the data into spatial data, digitize spatial data and input attribute data.

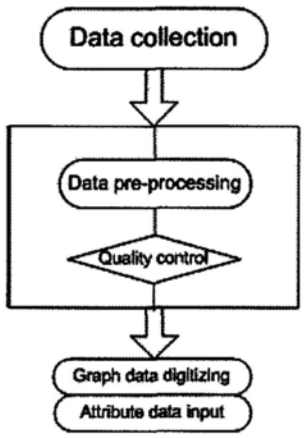


Fig. 3.4 Flowchart of building the database

3.4 Research Methodology

In the analysis of medical services in republican Beijing, we attempt to reveal the spatial patterns of TCM and Western medical services and their correlations with a wide range of variables. The approach used in the spatial data analysis is a data-driven approach, which is reflected in the selected techniques for describing and visualizing spatial distributions, identifying atypical localizations, detecting patterns of spatial association, and suggesting spatial regimes or other forms of spatial heterogeneity (Bailey and Gatrell 1995; Anselin 1998a,b). Four kinds of analytical methods are chosen and integrated to analyze the medical services in Beijing, including two-SFCA method, buffer analysis, spatial autocorrelation and GWR.

3.4.1 Spatial accessibility

Health care accessibility has been an important content for public health studies (Thouez et al 1988; Kivell et al 1990; Khan 1992; Khan and Bhardwaj 1994;). Two basic important factors involved in the issue of access to health care services are physicians (supply) and population (demand). Both are spatially spread but their distributions do not necessary coincide. Thus, access to health care varies across space. Measures of spatial accessibility include regional availability and regional accessibility (Joseph and Phillips 1984). The former is expressed as a population (demand) to practitioner (supply) ratio within a region, and it is simple and easy to implement. The latter considers complex interaction between supply and demand in different regions based on a gravity kernel, and it is less intuitive and requires more computation (Wang and Luo 2005).

The regional availability approach has two problems: interaction across regional boundaries is generally not adequately accounted for and spatial variability within a region is not revealed (Wing and Reynolds 1988). A two-SFCA method (Radke and Mu 2000) has been developed to overcome these fallacies. The two-SFCA method is in fact a special case of a gravity-based method (Luo and Wang 2003) and even produces better accessibility ratios than the kernel density method

(Yang et al. 2006). Therefore, we adopt the two-SFCA method to explore the distributions of TCM and Western medical resources in Beijing.

3.4.2 Spatial proximity

Buffer analysis is a common type of analysis with GIS, which is used for assessing proximity. It allows for the computation of simple circular buffers at varying distances around points, lines and polygons. This type of analysis is very useful for historical studies, in particular when dealing with transport data such as rivers or routes. In our study, the buffer analysis is used to calculate differences in the distributions of TCM and Western medical providers within buffers along roads of different levels to ascertain whether Western medical services were more closely related to the urban traffic. Furthermore, proximity analysis is combined with the accessibility analysis discussed in the last section in order to enhance the understanding between the relationship of TCM, Western medical services and urban traffic.

3.4.3 Spatial autocorrelation

Spatial autocorrelation is a fundamental feature of spatial data. It can be defined as "the coincidence of value similarity with locational similarity" (Anselin 2001). There is positive spatial autocorrelation when high or low values of a random variable tend to cluster in space and there is negative spatial autocorrelation when geographical areas tend to be surrounded by neighbors with very dissimilar values. Spatial autocorrelation may be caused by a variety of spatial processes, including, among others, interaction, exchange and transfer, and diffusion and dispersion. It may also result from missing variables and unobservable measurement errors in multivariate analysis. An important feature of spatial association is a form of serial arrangement similar to the one in the analysis of time series. This feature invalidates the assumption of independence, and compromises the applicability of conventional statistics, which may lead to biased and inconsistent estimates.

To measure the spatial autocorrelation, the most popular indicators are Moran I (Cliff and Ord 1981; Upton and Fingleton 1985), Geary's C statistics (Cliff and Ord, 1973) and G statistics (Getis and Ord 1992). That analysts would be more likely to choose Moran I is because the distribution characteristics of Moran I statistics is more satisfying. The Moran I is thus used to analyze the global spatial autocorrelation of TCM and Western medical services in Beijing.

Moran's I statistic is a global statistic and does not allow to assess the local structure of spatial autocorrelation. As we are concerned with the local spatial clusters of high or low values in the medical services, the local spatial autocorrelation is considered as well. Moran I, Geary's C statistics and G statistics all have their local forms of spatial statistics: Local Indicator of Spatial Association (LISA) (Anselin, 1994), Gi (d) Statistic (Getis and Ord 1992; Ord and Getis 1995, 2001) and local Geary C statistic (Anselin, 1994). They are applied for different purposes: Both Gi (d) statistics and LISA allow detecting places with unusual concentrations of high or low values (i.e., 'hot' or 'cold' spots), while local Geary C statistics allows the test of similarity or dissimilarity of local pattern. The Gi (d) statistics can easily identify 'hot' or 'cold' spot areas and it is thus referred to as "hotspot analysis". We adopt the hotspot analysis to analyze the local spatial autocorrelation of TCM and Western medical services in Beijing.

3.4.4 Spatial non-stationarity

The ordinary linear regression (OLR) model has been one of the most useful statistical methods to identify the nature of relationships among variables (Dobson 1990). However, in many real-life situations, there is ample evidence for the lack of uniformity in the effects of space. Variation or spatial non-stationarity in relationships over space commonly exist in spatial data sets and the assumption of stationarity or structural stability over space may be highly unrealistic (Anselin 1988; Fotheringham et al 1996; Fotheringham 1997a). It is shown that a) relationships can vary significantly over space and a `global' estimate of the relationships may obscure interesting geographical phenomena; b) variation over space can be sufficiently complex that it invalidates simple trend-fitting exercises (Brunsdon et al 1996). So, we cannot just apply the global regression model when analyzing the relationships between medical services and various variables. We need to deal with both global and local patterns at the same time.

Some spatial analytical methods have been developed to measure spatial non-stationarity. These techniques include the expansion method (Casetti 1972; Jones and Casetti 1992), the method of spatial adaptive filtering (SAF) (Foster and

Gorr 1986; Gorr and Olligschlaeger 1994), the random coefficients model (Aitken 1996), the multilevel modelling (Goldstein 1987), the moving window approach (Fotheringham et al. 1997a) and geographically weighted regression (GWR) (Brunsdon et al. 1996; Fotheringham et al. 1997a,b; Leung et al. 2000). Compared with other methods, GWR is relatively simple but effective in modeling complex spatial variation. It allows different relationships to exist at different points in space. Therefore, we employ GWR to examine the spatial variations in the relationships between TCM, Western medical services and various variables.

3.5 Summary

This chapter has established a Republican Beijing historical data management and it includes three parts: data collection, database management and data analysis. The data were collected and prepared according to six cultural spheres: public health cultures, urban morphology, market cultures, education cultures, legal cultures and religious cultures. The geo-database data model was used to represent and manage data. Buffer analysis, two-SFCA method, spatial auto-correlation and GWR were selected and integrated to investigate some aspects of the medical services in Republican Beijing. This is the framework for managing data and analyzing data in this study. A system will be established in which a historical GIS database is built and specific spatial analyses are applied.

CHAPTER 4: BUILDING REPUBLICAN BEIJING HISTORICAL GIS DATABASE

4.1 Introduction

This chapter examines the issues related to building the Republican Beijing historical GIS database. In section 2, we will discuss geo-referencing and digitizing historical maps to produce a base map. Section 3 presents an approach to working out the sequence of street numbers for the base map. Section 4 presents the capture of attribute data and a coding system linking the attribute data into spatial data. Section 5 presents the Modifiable Areal Unit Problem (MAUP) and our approach to zoning the 80 districts for the spatial analysis. Section 6 describes the metadata of the database. The last section is a summary of this chapter.

4.2 The Base Map

Four historical maps are prepared for creating the base map. a) The Survey map of Inner and Outer cities of Beijing produced by the Office of Surveying and Mapping, Zhifang Department, Ministry of the Interior at a scale of 1:8500 in 1913. b) The map of the inner and outer cities of the capital produced by the Office of Surveying and Mapping, Zhifang Department, Ministry of the Interior at a scale of 1:8000 in 1916. c) The survey map of the inner and outer cities of Beiping produced by the Public Works Bureau of the Beiping Municipal Government at a scale of 1:5000 in 1937 and d) The Beiping city map published by China Map Press at a scale of about 1:14285 in 1940. The 1937 map is treated as the main source of the base map and geo-referenced due to its higher spatial resolution. The other maps are matched to the 1937 map by using rubber-sheeting.

4.2.1 Spatial matching of historical maps

The spatial matching of historical maps is a process of map-to-map registration. The registration is the translation and rotation alignment process by which two maps of like geometries and of the same set of objects are positioned coincident with respect to one another so that corresponding elements of the same ground area appear in the same place on the registered maps (Haralick 1980). The specific steps and their algorithmic methods are illustrated as below:

4.2.1.1 Specific steps

Step 1: Find out a mathematical model. Establish the relationship between the registered map coordinate (x,y) (frequently that of lower resolution) and reference map coordinate (u,v) (frequently that of higher resolution) and calculate the map coordinate (x,y).

Step 2: Resample. Because the registered map coordinate (x,y) calculated is usually not in the middle of the pixel, it is required to re-calculate the coordinate (x,y) by using interpolation methods.

4.2.1.2 Algorithmic methods

1. Mathematical model establishment

Establish the mathematical relationship between the registered map and reference map:

$$\left.\begin{aligned} x &= f_x(u,v) \\ y &= f_y(u,v) \end{aligned}\right\} \qquad (4.1)$$

The function f is often represented as a binary polynomial:

$$\left.\begin{aligned} x &= \sum_{i=0}^{n}\sum_{j=0}^{n-i} a_{ij}u_i v_i \\ y &= \sum_{i=0}^{n}\sum_{j=0}^{n-i} b_{ij}u_i v_i \end{aligned}\right\} \qquad (4.2)$$

Where (x,y) is the registered map coordinate, (u,v) is the reference map coordinate, a_{ij} , b_{ij} are undetermined polynomial coefficients n=1,2,3….

First, Select control points, calculate their coordinates (x_k, y_k), (u_k, v_k) and work out the undetermined polynomial coefficients a_{ij}, b_{ij} by using least squares method.

Second, work out the registered map coordinate (x,y) based on the row and column values of each pixel.

2. Spline transformation

Rubber sheeting is a procedure for adjusting the coordinates of all the data points in a dataset to allow a more accurate match between known locations and a few data points within the dataset. It preserves the interconnectivity between points and objects through stretching, shrinking, or reorienting their interconnecting lines. When enough links are created, the raster dataset can be transformed to permanently match the map coordinates of the target data. A polynomial, spline, or adjust transformation can be used to determine the correct map coordinate location for each cell in the raster.

The spline transformation is a true rubber sheeting method and optimizes for local accuracy but not global accuracy. It is based on a spline function, which is a piecewise polynomial that maintains continuity and smoothness between adjacent polynomials (Franke 1982; Mitas and Mitasova 1988).

The spline function uses the following formula for the surface interpolation:

$$S(x,y) = T(x,y) + \sum_{i=1}^{N} \lambda_j R(r_j) \qquad (4.3)$$

where: j = 1, 2, ..., N , N is the number of points, λ_j are coefficients found by the solution of a system of linear equations, r_j is the distance from the point (x,y) to the j th point. T(x,y) and R(r) are defined differently, depending on the selected option.

For the regularized option:

$$T(x,y) = a1 + a2x + a3y \qquad (4.4)$$

$$R(r) = \frac{1}{2\pi}\left\{\frac{r^2}{4}\left[\ln(\frac{r}{2\tau} + c - 1)\right] + \tau^2[K_0(\frac{r}{\tau}) + c + \ln(\frac{r}{2\pi})]\right\} \qquad (4.5)$$

and for the tension option:

$$T(x,y) = a1 \qquad (4.6)$$

$$R(r) = -\frac{1}{2\pi\varphi^2}\left[\ln\left(\frac{r\varphi}{2}\right) + c + K_0(r\varphi)\right] \quad (4.7)$$

Where: τ^2 and φ^2 are the parameters entered at the command line, r is the distance between the point and the sample, K_0 is the modified Bessel function, c is a constant equation to 0.577215, a_i are coefficients found by the solution of a system of linear equations.

Spline transforms the source control points exactly to target control points and the pixels that are a distance from the control points are not guaranteed to be accurate. This transformation is useful when the control points are important and they are required to be registered precisely. As we want to compare the maps of different dates to see the changes in hutong and streets, we adopt the spline transformation with the aim of registering the historical maps more precisely.

4.2.1.3 Selection of control points

The first step of spatial matching is to select the control points from the registered and reference maps and then work out the cognominal polynomial coefficients. We selected the appropriate control points and used the small region partition method. Control points should be those features that seldom change with the lapse of time. Based on the landscape features of Beijing City, the major control points include the junctions and the two ends of rivers and hutongs, the turning points of particular buildings like city gates, gate walls. Spline requires a minimum of ten control points. The more the control points, the higher the accuracy. There are more than 400 control points selected for each registered map. For instance, we selected 483 control points for the 1916 map to conduct geometric correction and spline is the interpolation method used. Fig. 4.1 shows the 1916 map registered. This procedure is realized by using geo-referencing function in Arc/GIS 9.3.

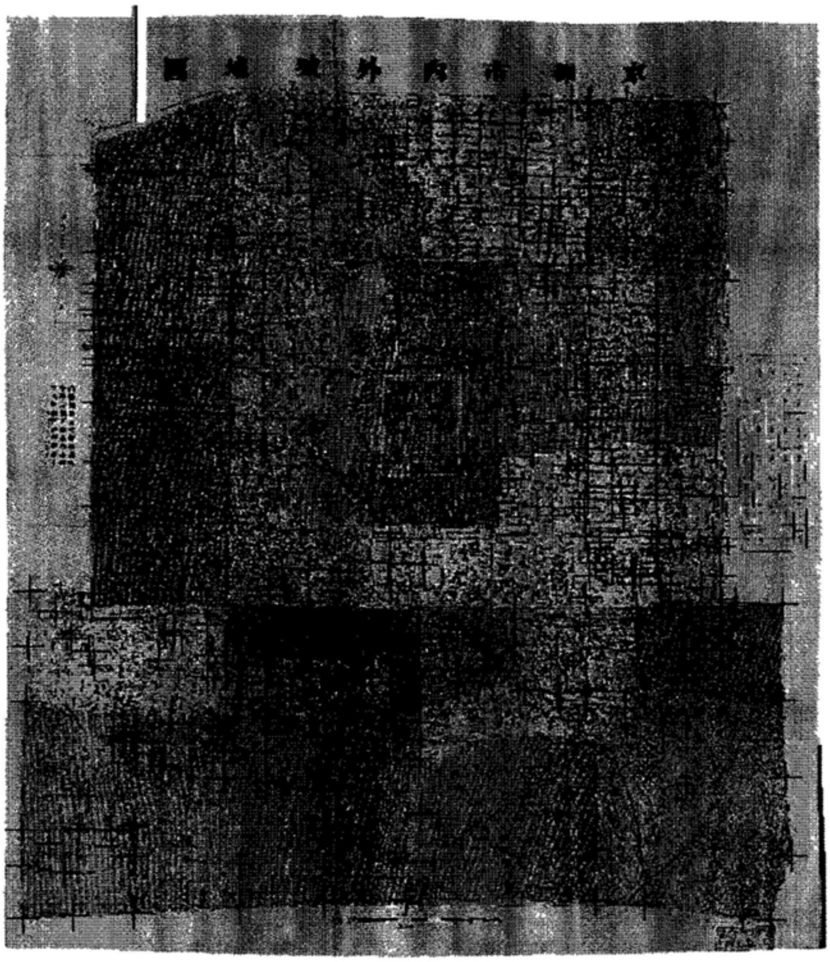


Fig. 4.1 The 1916 map registered.

4.2.2 Digitizing base map

All these city maps are showing the hutong (alleys and streets) grid of the city, which constitutes the basic urban structure. The 1937 map (Fig. 4.2) is treated as the main source of base map and digitized due to its high spatial resolution. Because the 1937 map is too old, there are quite a few hutongs whose names are not decipherable.

Some can be verified and corrected through the comparison with the 1913, 1916 and 1940 maps. However, it cannot be completed because the information on the 1937 map is much more detailed than the other two maps. To further enhance the quality of our data, we make use of the Hutong of Beiping published by Economic News Press in 1936. This book contains detailed information about hutong and streets and is useful for proof-reading and correcting the hutong names on the 1937 map. In this way, more than 3100 hutongs (i.e. line features) are reconstructed. The basic blocks (i.e. polygons) and important organizations such as schools, temples, police stations, identified as points on the map legend are digitized. In addition, the police districts (i.e. polygons) are georeferenced. The boundaries of 11 districts are derived from the 1937 map directly while the boundaries of 20 police districts are generated according to the 1916 map. Fig. 13 shows the base map digitized.

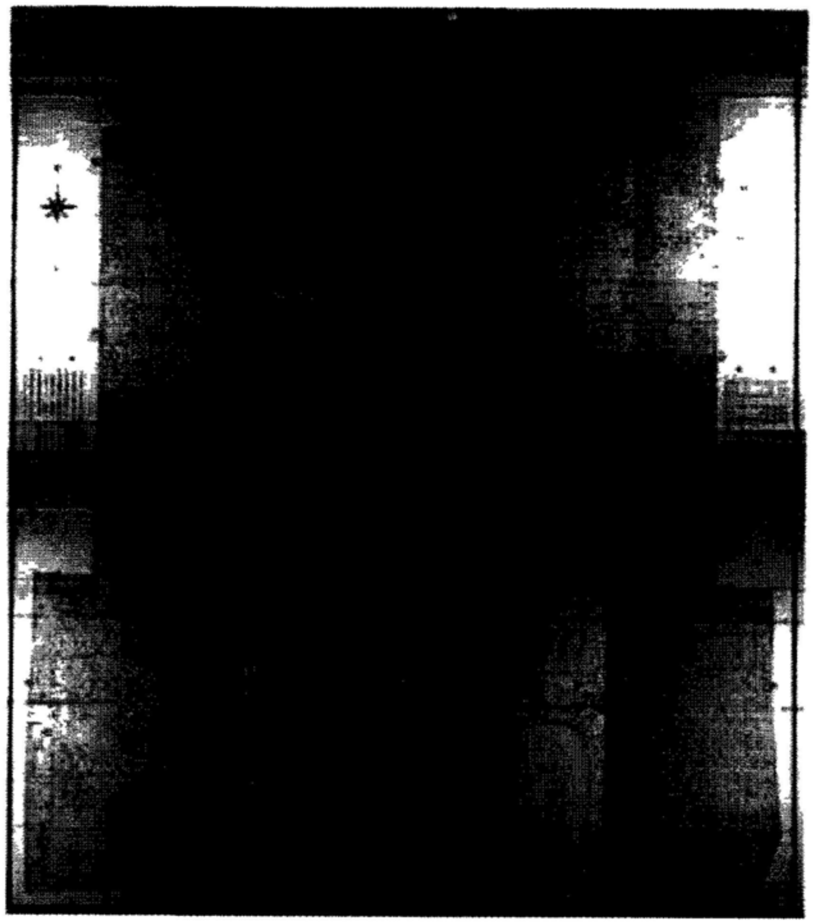


Fig.4.2. Survey map of inner and outer cities of Beiping in 1937

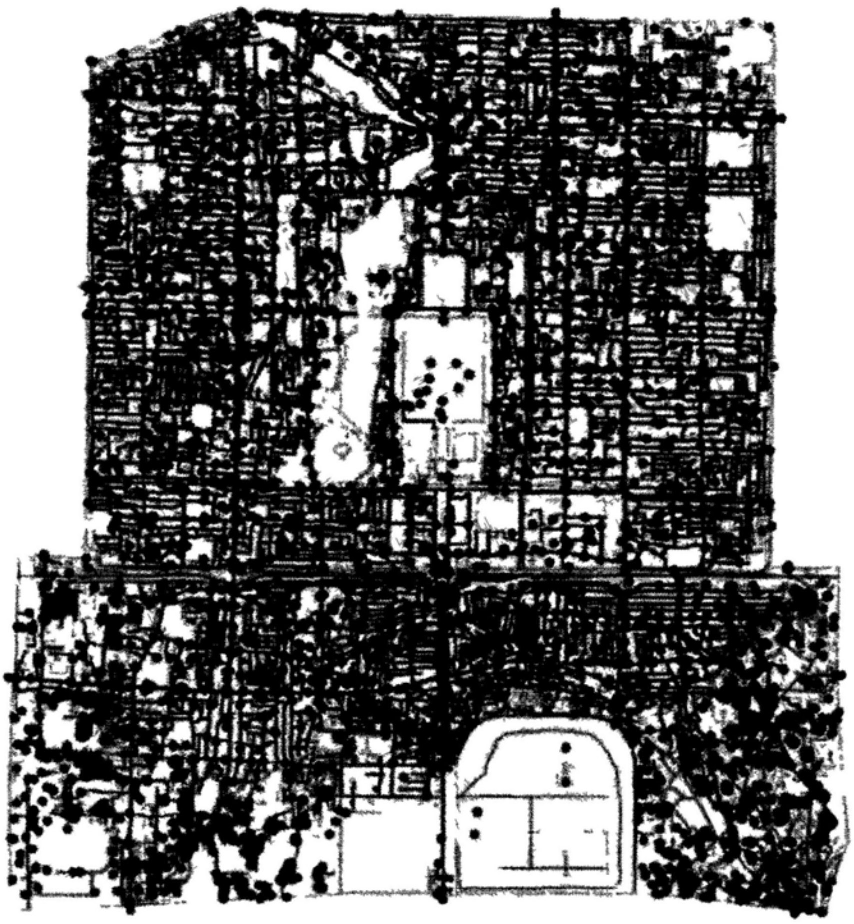


Fig.4.3 The base map digitized

4.3 Plot Feature Points

Most of the features of the database are represented as feature points. They are plotted according to their hutong addresses. There are a great number of addresses containing not only hutong information but also street number information. As presented in the last section, the basic geographic unit of the base map is hutong. Street number information is not shown on the base map. This is a frequently encountered problem when building an historical GIS database, caused by the limitation of the scale of the map. As historians have a long tradition of dealing with historical data, such problem can be solved by combining historical approaches with GIS. Our study provides a solution to work out the sequence of the street numbers for hutongs on the base map to plot feature points relatively accurately.

The main idea of this solution is to make good use of the important organizations such as schools, temples, hospitals and police stations, which appear as point symbols on the map legend. The thematic information about these organizations (containing street number information) derived from historical materials have been stored in an access database. It is assumed that there should be a matching relationship between these two kinds of data. The closer the dates, the stronger the relationship. The street numbers of the point symbols can be deduced by figuring out this relationship. Once the street number(s) of the point symbols on certain hutong are identified, the other feature points on this hutong will have a reference for plotting.

We utilize temple data to do this due to the fact that: a) we have 1928 and 1936 temple data, which contain large amount of thematic information including addresses, properties, numbers of rooms and so on. Among others, more than 80% of the addresses for temples have street number information. b) there are a great number of temple symbols on the map legend. In total, 462 temple symbols have been digitized on the base map. The 1937 map is supposed to provide the most accurate data among the existing maps, since the year of this map is the closest to the temple data. The 1916 map is used for reference because there are quite a number of temple symbols on this map. When the access data shows that there is a temple on a particular hutong, but the corresponding temple symbol cannot be found on the 1937 Beiping map, then the 1916 Beiping map will be used as reference.

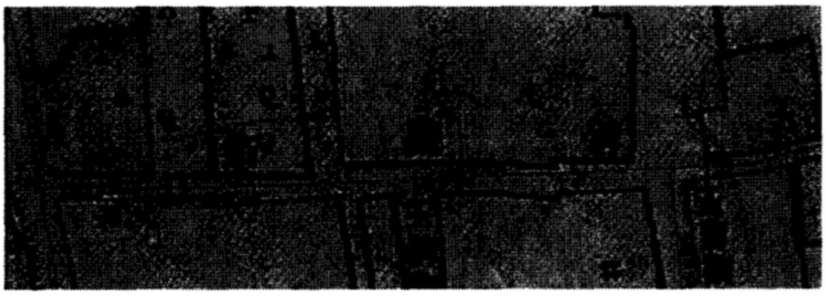
To begin with, several assumptions and principles have to be laid out:

1) The trend for each hutong is assumed to be following the direction of the hutong label shown on the map.

2) Odd and even street numbers are located on the different sides of hutongs. This can be seen in the location of symbols lying on the map, together with the access data. By making full use of the symbols, access data that matches with the symbols are plotted accordingly on the exact location where the symbols lie. Thus, the location of the symbols and the street number in the access data provide useful information on the general pattern of distribution of odd and even numbers on the hutong.

a

b



c

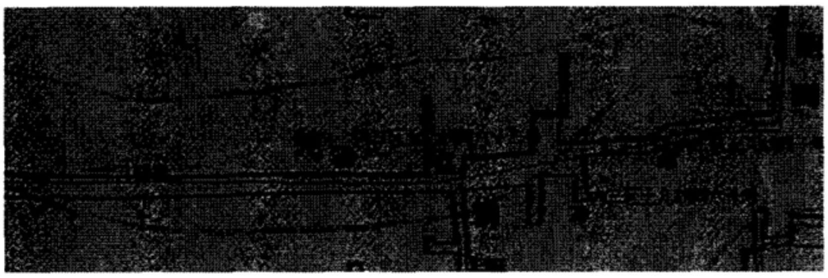


Fig. 4.4a,b,c. The general pattern of street number shown on horizontal hutongs

As shown in Fig. 4.4a,b,c, all odd street numbers lie on the upper part of the hutong, while even numbers on the lower part. This is the general pattern of distribution of odd and even street numbers shown on most of the horizontal hutongs.

a b

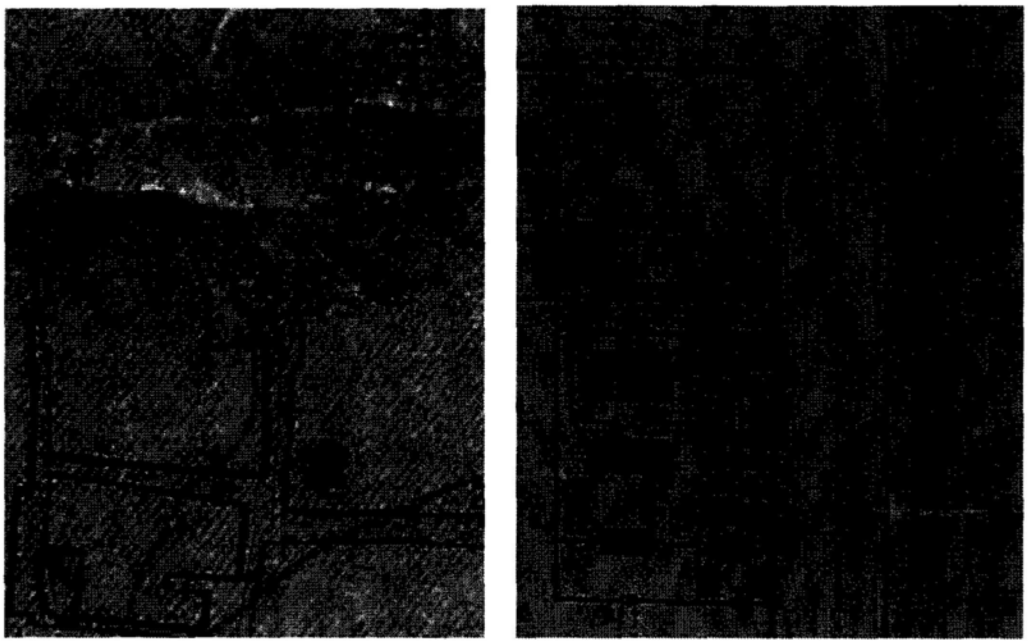


Fig 4.5a,b. The pattern of the odd and even street numbers on vertical hutongs

As for the vertical hutongs, the general pattern can be shown in Fig 4.5. Odd numbers are on the right hand side of the hutong, and even numbers of the left hand side. Such pattern can be seen in most cases and hence are considered to be the general pattern of distribution of odd and even street numbers.

3) We assume that temples with larger scales were more likely to be shown on maps. When there are fewer symbols on the hutong on the map than the access data, temples with higher number of rooms will be regarded as the symbols shown on maps.

4) Temples with a smaller street number should be plotted closer to the beginning of the hutong than temples with a larger street number.

5) For those temple records in access which can not be matched to the symbols, they will be plotted according to the street number. The location of a particular street number can be determined by the previously plotted points on the same hutong.

These principles will be illustrated by using some typical examples as below.

Case 1: The number of symbols on the map is equal to the number of temple records in access.

a) One symbol on the map, one record in access.

There is only one temple on *baoen'si hutong* 報恩寺胡同 in access (see table 4.1). On the 1937 map, there is only one symbol shown on this hutong (see fig.4.6). So the point is plotted on the spot according to the position of the symbol.

Table 4.1 ***Baoen'si hutong*** **報恩寺胡同 in access**

报恩寺	内三区报恩寺胡同十一号

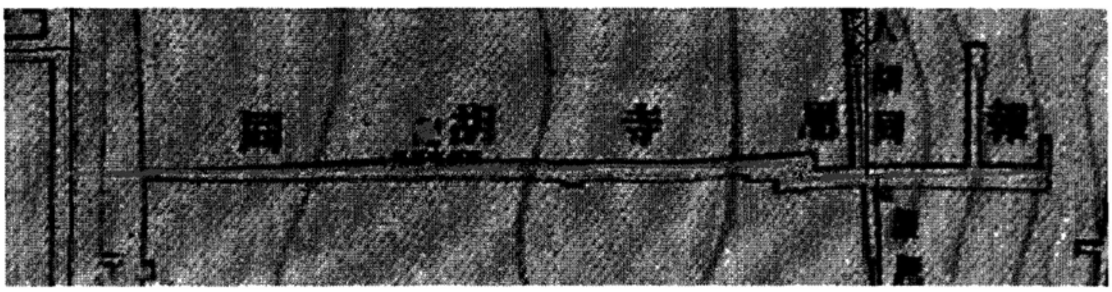


Fig. 4.6 ***Bao'ensi hutong*** **報恩寺胡同 on the 1937 map**

b) Two symbol on the map, two records in access.

There are two temples on *wuwanghou hutong* 武王侯胡同 in access(see table 4.2). On the 1937 map, there are also two symbols shown, with one labeled with the name of one of the temples. (see fig.4.7)

Table 4.2 ***Wuwanghou hutong*** **武王侯胡同 in access.**

宝禅寺	内四区武王侯胡同十
庆宁寺	内四区西四北武王侯

Fig. 4.7 ***Wuwanghou hutong*** **武王侯胡同 on the 1937 map**

From the Access data, there are two temples on *wuwanghou hutong* 武王侯胡同. To figure out which symbol represents which temple, we can take a look at the 1937 map. As shown in Fig. 4.7, the name of the temple *baochansi* 寶禪寺 is shown right above the temple symbol (highlighted in light blue) at *wuwanghou hutong* 武王侯胡同.Under this condition, the temple point representing *baochansi* 寶禪寺 can be plotted accordingly.

Case 2: Less symbols on map, more records in access.

a) There is one temple on *damochang* 打磨廠 in access (see table 4.3). However, there is no symbol shown on both maps, the point is plotted in the middle of the hutong.(see Fig.4.8a,b.)

Table 4.3 *Da mochang* 打磨廠 in access

观音阁	外一区打磨厂二六三号

a

b

Fig. 4.8a *Damochang* 打磨廠 on the 1937map and b on the 1916 map.

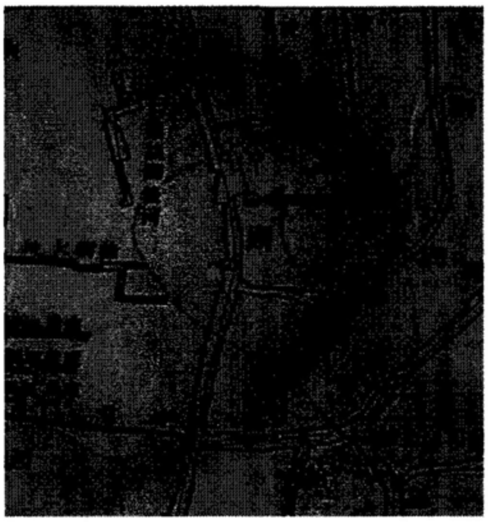
b)There are three temples on *shitou hutong* 石頭胡同 in access. (see table 4.4)

The two points as indicated by the arrows in Fig. 4.9 are symbols shown on both maps. Since the locations of both symbols are quite different, the two symbols are considered to represent two different temples. Based on the principle that temples with higher number of rooms have higher priority in matching data with symbols on maps, *zhun'tian* 准提庵 and *yan'shouan* 延壽庵 are hence plotted accordingly.

Table 4.4. ***Shitou hutong* 石頭胡同 in access.**

莲花寺	外二区石头胡同五号
准提庵	外二区石头胡同二十一号
延寿庵	外二区石头胡同九十二号

a b



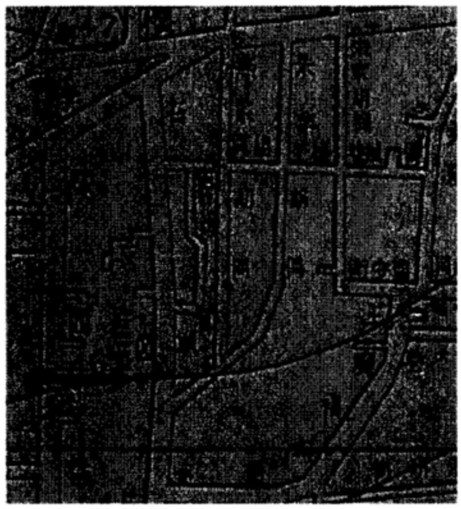


Fig. 4.9a S*hitou hutong* 石頭胡同 on the 1937map and b on the 1916map

Case 3: There are more symbols shown on the map than the number of temples shown in the access data.

Table 4.5. ***Shitou hutong* 石頭胡同 in access.**

財神庙	内五区鼓楼东大街四十六号

a

b

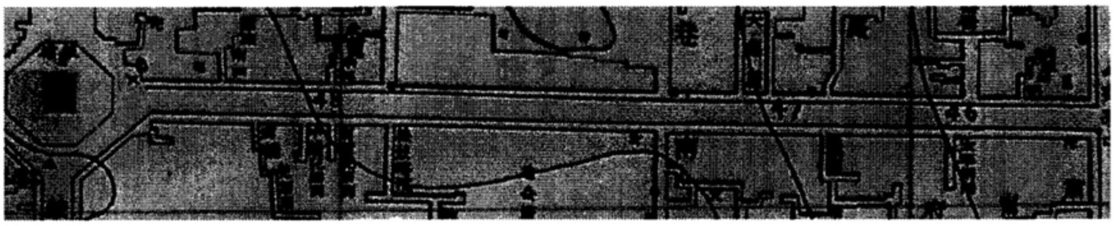


Fig 4.10a *Guloudong dajie* 鼓樓東大街 on the 1937 map and b on the 1916 map

While there is only one temple in the access data (see table 4.5), both maps show two temple symbols. In this case, *caishenmiao* 財神廟 is hence plotted in the middle of*gu'loudong daji* 鼓樓東大街.

There are some possible reasons causing this situation:

a) There were some new temples appearing in one year's time.

b) There were some temples not registered.

c) There were some temples occupied by homeless people.

Case 4: 1916 map provides more temple symbols than 1937 map on the same hutong.

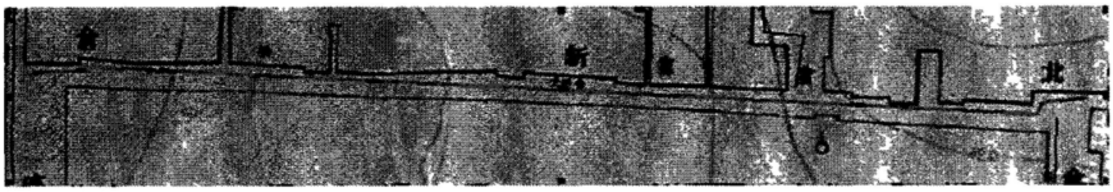
a) There is one temple on *Beixincang* 北新倉 in access (see table 4.6). On the 1937 map, there is no symbol shown on the hutong(see fig. 4.11a), while the 1916 map shows the same number of symbols as the number of temples in the access data (see fig. 4.11b).

So the point is plotted according to the location as shown on the 1916 map.

Table 4.6 *Beixincang* 北新倉 in access

关帝庙	内三区北新仓五十三号

a



b

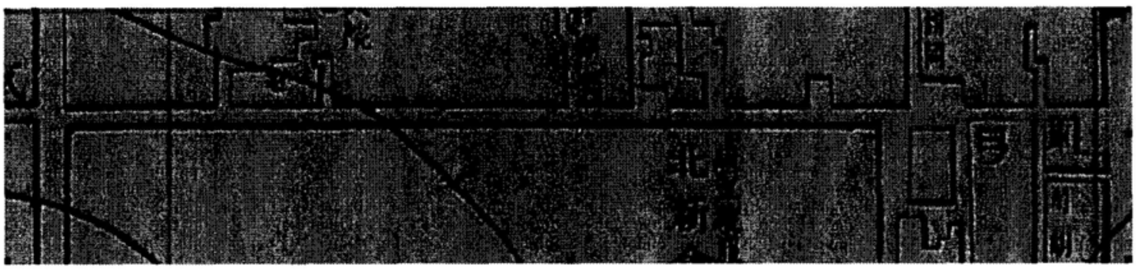


Fig. 4.11a *Beixincang* 北新倉 on the 1937 map and b on the 1916 map

b) Access data shows two temples located on *zhongsitiao* 中四條 (see table 4.7). On the 1937 map, there is only one symbol shown on the hutong (see fig.4.12a), while the 1916 map shows two symbols on the same hutong (with one located on the spot similar to that shown on 1937 map) (see fig.4.12b).

Table 4.7 *Zhongsitiao* 中四條 in access.

关帝庙	外三区中四条四十三
寿佛寺	外三区中四条三十一

a

b

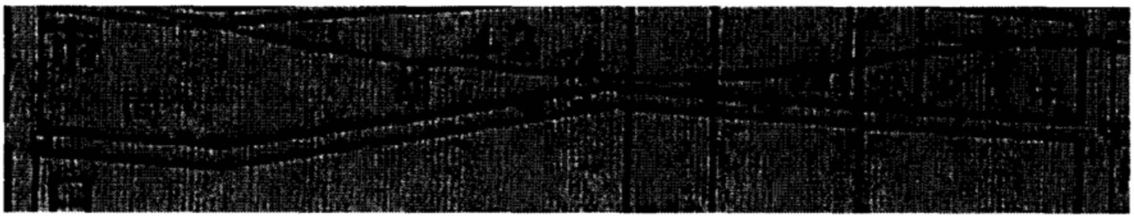


Fig. 4.12a *Zhongsitiao* 中四條 on the 1937 map and b on 1916 map

There is one more symbol shown on the 1916 map than the 1937 one. The second thing to be considered is the house number. Since the street number of *shoufosi* 壽佛寺 is 31, while that of *guandimiao* 關帝廟 is 43, it makes sense that *shoufosi* 壽佛寺 is to be plotted before *guan'dimiao* 關帝廟. Thus, *shoufosi* 壽佛寺 is plotted according to the location on 1937 map, while *guandimia* 關帝廟 following the location shown on 1916 map.

c) There are three temples on *xiaoshi dajie* 曉市大街 in access(see table 4.8).

Table 4.8 *Xiaoshi dajie* 曉市大街 in access

海潮庵	佛庙	外五区晓市大街四十四号
真武庙	道庙	外五区晓市大街四号
财神庙	道庙	外五区晓市大街一二七号

a

b

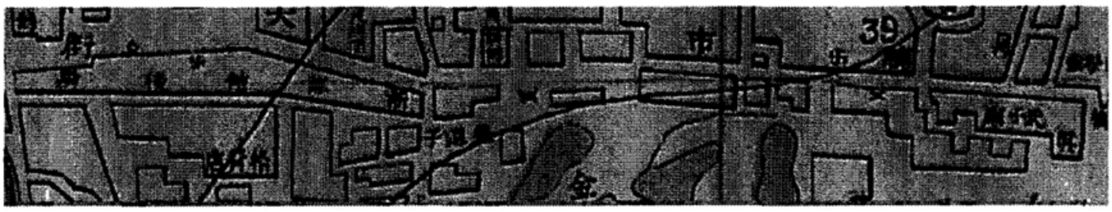


Fig 4.13a *Xiaoshi dajie* 曉市大街 on the 1937 map and b on the 1916 map.

There is only one symbol found on the 1937 map (see fig.4.13a), but there are three symbols found on the 1916 map (see fig.4.13b). One symbol is labeled *zhenwumiao* 真武廟 (as shown on the right hand side of Fig. 4.13b) and the corresponding point can be placed on the symbol. The other two symbols are placed according to the street number, i.e. *caishenmiao* 財神廟 is placed on the hutong after *haichao'an* 海潮庵. These two points are placed on the corresponding symbols on the 1916 map. In this case, most of the points are plotted according to the 1916 map, since it provides more information.

d) There are two temples on *picai hutong* 辟才胡同 in access.

Table 4.9 *Picai hutong* 辟才胡同 in access.

石佛寺	内二区辟才胡同三十四号
天仙庵	内三区闢才胡同三十八号

a

b

Fig. 4.14a *Picai hutong* 辟才胡同 on the 1937 map and b on the 1916 map.

The street numbers of both temples are quite close together. But according to the 1937 map, the two symbols are quite far away, while in the 1916 map, the symbols are closer together to each other. In this case, it appears that the 1916 map provides more accurate data. Thus, the two points are plotted according to the 1916 map (Yet, since the symbol for *shifosi* 石佛寺 on both maps are located on a similar spot, it is plotted exactly on the symbol shown on the 1937 map).

Some exceptions that may not follow the principles and their solutions are also provided.

Case 1:

Table 4.10 *Dongchashi hutong* 東茶食胡同 in access.

白衣庵	崇文门外外一区东茶食胡同路南一百
地藏庵	外一区东茶食胡同一百十五号

a

b

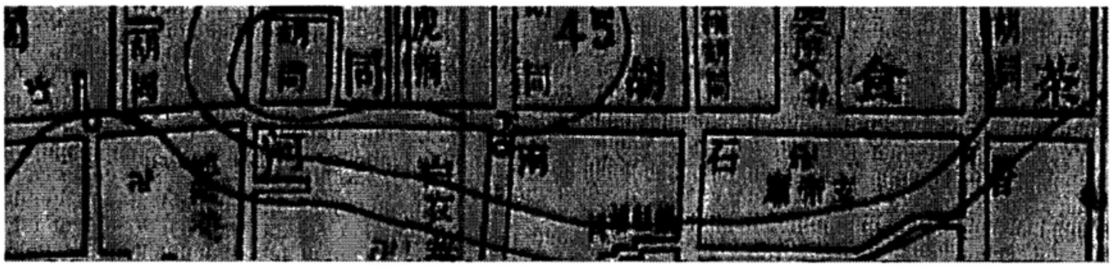


Fig.4.15a *Dongchashi hutong* 東茶食胡同 on the 1937 map and b on the 1916 map

As shown clearly in Fig.4.15a, there is no symbol on the 1937 map. Yet, in Fig.4.15b, there are two symbols: *dizang'an* 地藏庵 and *baiyi'an* 白衣庵 with labels showing the name of the temples on *Dongchashi hutong* 東茶食胡同. Although both symbols are not placed that closely to *Dongchashi hutong* 東茶食胡同, it is clear that both are the temples in the access data. Thus, the two temples are plotted according to the labels shown on the 1916 map, but leaning closer to *Dongchashi hutong* 東茶食胡同.

Case 2: There are one temple on 燈市口 in access.

Table 4.11 Dengshikou 燈市口 in access

二郎庙	东四南大街灯市口路东一七三号

Fig.4.16 *Dengshikou* 燈市口 on the 1937 map

Since the address indicates that the location of this temple is on the east of *Dengshikou* 燈市口, the symbol located right at the junction of the *Dengshikou* 燈市口 and *Dongsinan dajie* 東四南大街 would probably be 二郎廟 (See Fig. 4.16). Thus, the point is plotted on this symbol.

Case 3: There are three temples on *Dongan'men* 東安門大街 in access.

Table 4.12 *Dongan'men* 東安門大街 in access

崇宁寺	内一区东安门大街六十六号
关帝庙	内一区东安大街五十号
真武庙	内六区东安门大街四十五号

a

b

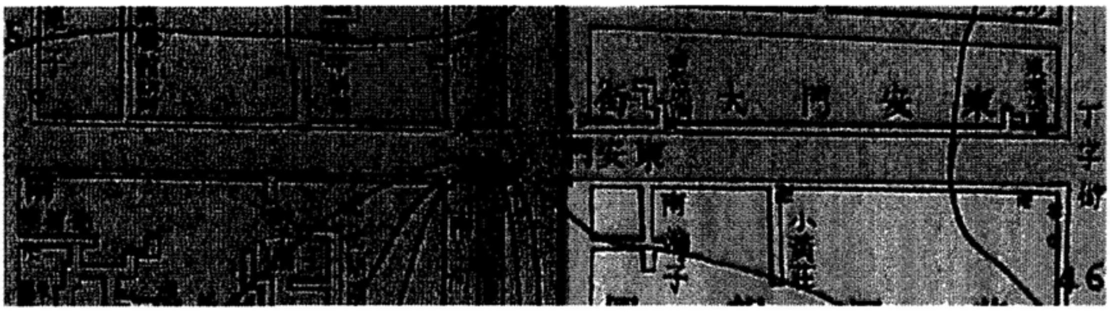


Fig.4.17a *Dongan'men* 東安門大街 on the 1937 map and b on the 1916 map.

Note that there are differences in the location of the three symbols on the two maps (see Fig.4.17a,b). While *Guandimiao*關帝廟and *Chongningsi*崇寧寺 are plotted according to the 1937 map, *Zhenwumiao*真武廟 is plotted based on the 1916 map. The symbol near *Xioahuangzhuang*小黃莊 is taken as a reference point because it makes more sense when looking at the street number of *zhenwumiao*真武廟.

Now we have a standard for the sequence order of street numbers and can plot the other features with street number information accordingly. For those features without street number information, they are plotted in the middle of the hutong.

4.3 Entry and Management of Attribute Data

4.3.1 Sources

While the spatial data are captured through digitizing, the attribute data are acquired through the investigation of historical materials. The dataset is collected from the Beijing Municipal Archive, National Library, Capital Library, 2nd Historical Archive in Nanjing, Institute of Modern History, Academia Sinica in Taipei, The Library of Congress and The Rockefeller Archival Centre in Tarrytown, New York. These are official census, reports, statistics, registries, private surveys, reports, directories, guidebooks, maps, accounts, books and other publications. A detailed bibliography of the database is provided in the reference section.

4.3.2 Entering and storing attribute data

The attribute data are stored in separate tables and the access database is chosen as the DBMS (database management system) to manage these tables. Access database is a certain kind of relational database, which have two prominent advantages over the other database types such as flat file, hierarchical and network (Laurini and Thompson 1992, Worboys 1995):

a) Each table in the database can be prepared, maintained and edited separately. This is very important for this study because many data in the database are recorded and managed according to spatial units.

b) These tables remain separate when it is needed to link different tables for inquiry and analysis purposes.

The first step of attribute data entry is to define the fields for each table in access according to historical materials. The field definition usually includes data width, data type and decimal digits. The attribute data are then input into the access database accordingly.

4.3.3 Linking attribute data into spatial data

The attribute data are linked to the spatial data by using a unique ID. Beijing city contains a multi-level administrative division system shown in fig.1. Beijing was divided into Inner City (i.e. North City) and Outer City (i.e. South City). Among the 11 police districts, six were in Inner City and five in Outer City. Each police district contained hundreds of hutongs and each hutong might contain several feature points. The unique ID system for the features (i.e. hutong and features of six cultural spheres) is designed in a way which indicates this administrative relationship. Table 1 shows the unique ID coding system. The first level (the top level) shows the cultural sphere that the feature belongs to, and then followed by the second level showing which city the feature was located, and the third level shows the district information and lastly the numbers of hutong and feature on the bottom level. It is assumed that the number of hutongs for each police district was no more than 1000 and the number of features on the same hutong for the same table is less than 20. So each hutong or feature is coded from top level to the bottom level, as shown in Fig.4.18, i.e. cultural sphere → city → district →hutong → feature. The way to number the hutongs and feature points is following the sequences they are digitized. So the ID for hutong has seven units/digits and the ID for feature points has nine units/digits. For instance, xiehe hospital was located at *shuaifuyuan* 帥府園, according to the coding system, the unique ID for feature point xiehe hospital is "311019301".

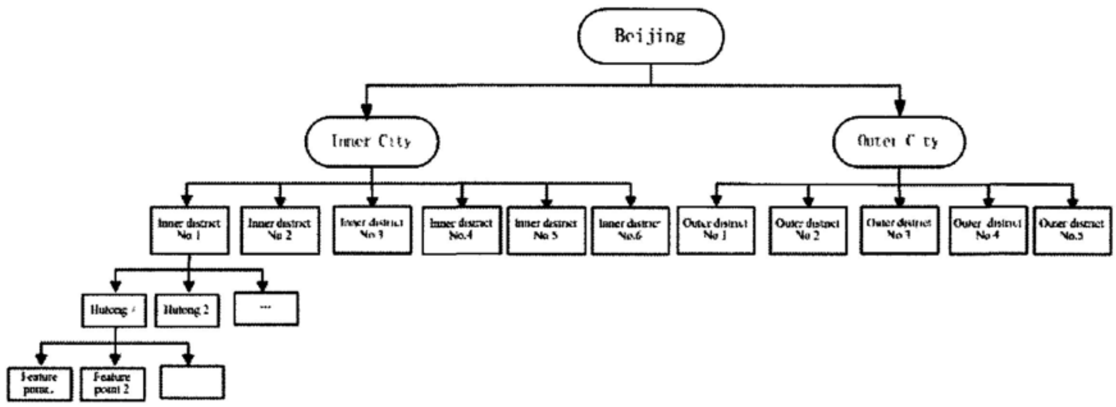


Fig.4.18 Multi-level Administrative Division System of Beijing city

Table 4.13 : Unique ID coding system

Cultural sphere						City		District						Hutong number	Point featu number
Urban morphology	Religion	Health	Legal	Education	Market	Inner	Outer	1	2	3	4	5	6	XXXX	XX
1	2	3	4	5	6	1	2	1	2	3	4	5	6	e.g. 0001	e.g. 01

4.4 Modifiable Areal Unit Problem: 80 Districts

Urban analysis is frequently conducted using 'aggregate' geographical data – i.e., data reported for pre-defined areal units such as census tracts and traffic analysis zones. A well-known spatial analytical issue that can influence the results of such studies is known as the modifiable areal unit problem (MAUP). The seriousness of this issue is clearly demonstrated by the spatial analytical techniques whose results are known to be affected by it (Goodchild 1979; Fotheringham et al. 1995; Hodgson et al. 1997; Murray and Gottsegen 1997).

The MAUP arises in urban analysis due to the fact that an infinite number of zoning systems could be constructed to subdivide a city into smaller areal units. This implies that the data reported for areal units will differ between zoning systems. A direct consequence of this is that results will vary for studies using the same analytical technique, but different zoning systems for the same city. The MAUP has two components: the scale effect and the zoning effect. The scale effect is a consequence of spatial aggregation while the zoning effect results from the multitude of zoning schemes that could be constructed and used at any given scale.

The simplest of the strategies for mitigating MAUP effects is to employ the smallest areal units available (i.e., base zones) in an effort to report the sensitivity of analytical results to scale and zoning effects (Wong 1996; Fotheringham et al. 2000). If it can be demonstrated that the results are stable over a wide range of zoning systems, then the analyst can express confidently that the results are meaningful and not simply artefacts of the way the data are partitioned in space (Fotheringham et al. 2000). It is obvious that this strategy requires that new zoning systems be created by merging base zones. This research will tackle this problem by using an approach to creating 80 new districts to be the basic areal units for conducting spatial analysis.

4.4.1 Zoning of 80 Districts

When taking 20 or 11 police districts as the basic administrative units to carry out spatial analysis, there would be two disadvantages: first, the scale would be too large to reveal the details of variations in the spatial patterns to be examined. Second, it would be lacking a necessary degree of freedom when applying spatial statistics due to the small number of observations. Thus, it is necessary to use smaller areal units for the spatial analysis. In this study, the main idea is to group the blocks on the base map together into new districts. However, this would confront the problem of how to allocate the population data of police districts into each block. We have adopted a solution illustrated as below (We are indebted to David W. Wong for suggesting this method):

First, work out the residential area for each polygon in block layer. Mark all the buildings of known a non-residential nature such as government offices, libraries, schools, hospitals, markets, temples, churches as well as open public spaces, old palaces, and lakes and hence generate an informed map of residential polygons. The residential area of each polygon should exclude the non-residential buildings, the formula is expressed as:

$$RP_i = AP_i - \sum_k NR_{ik} \times n \qquad (4.8)$$

Where RP_i is the residential area for polyon i, AP_i is the area of each polygon, and NR_{ik} is the area of the k^{th} non-residential building for polygon i and n is the number of the k^{th} non-residential building.

Second, work out the total area of the residential polygons R_j for each police district *j*, given as:

$$R_j = \sum_{i \in j} RP_i \qquad j = 1,2,3,\ldots 11 \text{ or } i = 1,2,3,\ldots 20 \qquad (4.9)$$

Where RP_i is the residential area of polygon *i* contained by police district *j*, that is $i \in j$.

Third, work out the density of population DP_i for each polygon, given as:

$$DP_i = \frac{P_j}{R_j} \qquad (4.10)$$

Where P_j is the population for police district *j*.

Finally, work out the population P_i for each polygon *i*, given as:

$$P_i = DP_i \times RP_i \qquad (4.11)$$

The population represented in this layer only represents that of a particular year. If the population of another year is available, the same process of factoring in the new numbers for each district can be done and another layer of population data based on building polygons can be generated. The key is to have the population year close to the map's year. For instance, we should only use population of 1937, or nearby years, for residential polygons shown on the 1937 map. These data should not be applied to the maps of the 1920's and 1910's. Now we can impose whatever zoning we want onto the base map and have the population of each newly defined zone at hand readily.

For our purpose, we divide the 20 districts into 80 sub-districts according to regular polygons and main streets. There are two reasons for this: First, 20 police districts are the raw data available. Second, after carefully examining the boundaries of the 20 police districts on the 1916 map, we find out that main streets and blocks should have been the major consideration in the zoning of 20 police districts. For example, the boundaries of inside right no.4 include *Xinjiekou* street, *Fuchengmen* street while the boundaries of inside right no.3 include *Jiugulou* street and *Gulou* street. The new 80 districts are then created accordingly and treated as the basic areal units for spatial analysis in this study. The applications of two-SFCA method, spatial autocorrelation and GWR in the following sections are all carried out based on the 80 sub-districts.

4.4.2 Mapping of Residential Areas

All spatial processing mentioned in the last section is carried out using Arc/GIS 9.3. During this process, the most challenging aspect is the mapping of residential areas because the non-residential areas were not clearly identified on the base map. Fortunately, the 1940 map shows the categories of land use such as government offices, schools, temples, churches and their areas, from which the non-residential areas can be calculated. We assumed that the residential areas were little changed in three years' time (i.e. from 1937 to 1940), and the non-residential area information on the 1940 map was then transferred to the base map. The residential areas were acquired by eliminating the non-residential areas in the polygon layer.

4.5 Metadata

Since creating a historical GIS database is often time consuming and expensive, it is very important to create metadata to ensure the long-term usability of the database. Metadata means "data about data", which is used to describe the content, quality, condition and other characteristics of the data contained in a database. It answers questions about data: what, where, when and who. By using metadata, the database manager and users can learn and distinguish datasets and then further utilize or manage datasets. This is an effective way to manage and apply historical databases. We have established the Republican Beijing GIS catalog based on metadata for data documentation and dissemination.

4.5.1 Main contents of core metadata

The metadata standards used in the present research include Dublin Core (2005), ISO19115 Geographic Information-metadata (2003) and Chinese Geographic Information – Metadata standard (1999). Table 1 shows the main contents of core metadata for geographic datasets.

Table 4.14 Core metadata for geographic datasets (from ISO 19115: 2003)

Dataset title (M) (MD_Metadata > MD_DataIdentification.citation > CI_Citation.title)	**Spatial representation type** (O) (MD_Metadata > MD_DataIdentification.spatialRepresen tationType)
Dataset reference date (M) (MD_Metadata > MD_DataIdentification.citation > CI_Citation.date)	**Reference system** (O) (MD_Metadata > MD_ReferenceSystem)
Dataset responsible party (O) (MD_Metadata > MD_DataIdentification.pointOfContact >	**Lineage** (O) (MD_Metadata > DQ_DataQuality.lineage > LI_Lineage)

CI_ResponsibleParty)	
Geographic location of the dataset (by four coordinates or by geographic identifier) (C) (MD_Metadata > MD_DataIdentification.extent > EX_Extent>EX_GeographicExtent > EX_GeographicBoundingBox or EX_GeographicDescription)	**On-line resource** (O) (MD_Metadata > MD_Distribution > MD_DigitalTransferOption.onLine > CI_OnlineResource
Dataset language (M) (MD_Metadata > MD_DataIdentification.language)	**Metadata file identifier** (O) (MD_Metadata.fileIdentifier)
Dataset character set (C) (MD_Metadata > MD_DataIdentification.characterSet)	**Metadata standard name** (O) (MD_Metadata.metadataStandardName)
Dataset topic category (M) (MD_Metadata > MD_DataIdentification.topicCategory)	**Metadata standard version** (O) (MD_Metadata.metadataStandardVersi on)
Spatial resolution of the dataset (O) (MD_Metadata > MD_DataIdentification.spatialResolution > MD_Resolution.equivalentScale or MD_Resolution.distance)	**Metadata language** (C) (MD_Metadata.language)
Abstract describing the dataset (M) (MD_Metadata > MD_DataIdentification.abstract)	**Metadata character set** (C) (MD_Metadata.characterSet)
Distribution format (O) (MD_Metadata > MD_Distribution > MD_Format.name and MD_Format.version)	**Metadata point of contact** (M) (MD_Metadata.contact > CI_ResponsibleParty)
Additional extent information for the dataset (vertical and temporal) (O) (MD_Metadata > MD_DataIdentification.extent > EX_Extent> EX_TemporalExtent or EX_VerticalExtent)	**Metadata date stamp** (M) (MD_Metadata.dateStamp)

Based on the core metadata, the database catalog is established (see appendix A). Now the users can learn the basic state of the datasets and their access location quickly by using this catalog.

4.6 Summary

We have built the Republican Beijing historical GIS database. Four historical maps of 1913, 1916, 1937 and 1940 were used to create the base map as the foundation of spatial data. The rubber sheeting method was used to geo-reference historical maps. Spatial data were acquired through digitizing while attribute data were derived from historical materials and then stored in access database. A coding system was developed to link the spatial data with attribute data. The metadata of the database were documented according to the standards of Dublin Core, ISO19115 Geographic Information-metadata and Chinese Geographic Information – Metadata standard.

There were two problems encountered when building this historical GIS database. One was that the digital representation is of lower accuracy to the sources due to the limitation of the scale of the base map. There was a great deal of Beijing medical historical information containing street number information which was not identified on the base map as the basic geographic unit of the base map was hutong. A solution was provided to work out the sequence of street numbers. This solution created a standard for the sequence order of street numbers, which improved the accuracy of the database. The other was the Modifiable Areal Unit Problem (MAUP).

There were only 11 or 20 police districts for Beijing city, which would limit the application of spatial analysis. We created 80 new districts and developed an approach to further break down the population pattern from 20 police districts to 80 districts. This process allowed us to conduct spatial analysis based on smaller areal unites, making it viable to reveal the details of variations in the spatial patterns of medical services in Beijing.

Building the Republican Beijing historical GIS database is a time-consuming and expensive undertaking which contains a large amount of work. However, this well-constructed and properly documented GIS database provides the research resource and structured in ways that no other approach can manage and allows the investigation of data from a wide range of different sources and dates. These are useful not only for answering the research questions, but also for providing a resource for scholars in many years to come.

CHAPTER 5: SPATIAL-TEMPORAL CHANGES OF TCM AND WESTERN MEDICAL SERVICES

5.1. Introduction

This chapter attempts to present the distributions and changes of TCM providers and Western hospitals in Beijing in republican period. In section 2, we will describe the data. Section 3 presents global spatial autocorrelation and the analytical results for the distributions of TCM providers and Western hospitals. Section 4 presents hotspot analysis and the analytical results for the distributions of TCM providers and Western hospitals. The last section is a summary of the findings.

5.2 Data Source

The spatial patterns of Western medical services are representing the locations and distributions of Western hospitals and clinics. While TCM services were widely supplied in TCM drugstores, clinics, temples, temple markets, and guilds. These data come from several sources. The 1914 Western hospital data (22 entries), 1914 TCM doctor data (16 entries) and 1914 (42 entries) and 1923 TCM drugstore data (170 entries), come from *Beijing Health Memorabilia*, published by Beijing Kexue Jishu Chubanshe, which is about the development of medical history in Beijing. The 1935 Western hospital data (94 entries) are derived from *Archives of Survey of General Hospitals in Beiping* with archive no. J1-03-53 and J1-03-54 and *Beiping City Government Health Board Business Report*. Both sources provided detailed information about the profiles of Western hospitals. The 1935 TCM drug store data

(300 entries) come from *Archive of List of Traditional Chinese Medicine Business in Beiping* with its archive no. J005-003-00037, which was the survey of TCM drug stores conducted by Beiping Municipal Bureau of Social Affairs. The 1930 TCM doctor data (366 entries) are derived from *Beiping TCM Union Roll* published by Beiping TCM Union, which contains information about the TCM doctors. The temple data are derived from *The Historical Materials of Temples in Beijing* compiled by Beijing Municipal Archive in 1997, which included temple registrations of 1928, 1936 and 1947. The 1928 and 1936 temple data are utilized in this study but we identify and use only those temples that claimed to provide TCM services in their records. There are 40 entries and 15 entries respectively. The 1916 temple data are derived from the 1916 map. There are only temple symbols shown on the map but without any evidence of whether they provided TCM services or not. We identify those temples overlapping with the 1928 and 1936 temples (providing TCM services) and treat them as the 1916 temple data. In this way, we get 32 entries for the 1916 temple data. The 1929 TCM doctor data (63 entries), 1929 Western hospital data (63 entries) and 1929 guild data (406 entries) come from *The Tour Guide of Beiping* compiled by Beiping democratic Socialist, which provided information about geography, politics, social-economy, local customs of Beiping. The 1937 temple market data (16 entries) are derived from *Beiping Temple Market Survey Report* compiled by Wang Yichang which was the survey of temple markets in Beiping. The temple market data of early republican period come from *Old Beijing Customs*

published by Beijing Yanshan Chubanshe in 1990, which is about the local customs of Beijing.

We use three time serials to explore the spatial changes of TCM and Western medical services in the republican period. These are 1910s, 1920s and 1930s. The TCM data used in this spatio-temporal analysis only include TCM drugstores, TCM doctors and temples because these data are complete for the whole periods. The incomplete temple market (data for 1920s are not available) and guild data (data for 1930s are not available) are then incorporated separately to validate the TCM patterns shown in the spatio-temporal analysis.

5.3 Global Spatial Autocorrelation

To measure the global spatial autocorrelation, the most popular indicator is Moran I (Cliff and Ord 1981; Upton and Fingleton 1985) defined by:

$$I(d) = \frac{\sum_{i}^{n}\sum_{j}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i}^{n}\sum_{j}^{n} w_{ij}} \qquad (5.1)$$

Where $S^2 = \frac{1}{n}\sum_{1}^{n}(x_i - \bar{x})^2$, x_i is the observed value at location i, $\bar{x}$ is the average of x_i over the n locations. w_{ij} is the spatial weight matrix between location i and j. The theoretical mean of Moran I is -1/ (n-1).

The standardized Moran I is positive when the observed value of locations within a certain distance(d) tend to be similar, negative when they tend to be dissimilar, and approximately zero when the observed values are arranged randomly and independently over space. The expected value and variance of the Moran I for samples of size n could be calculated according to the assumed pattern of spatial data distribution (Cliff and Ord 1981) and the normal test for the null hypothesis of no spatial autocorrelation between observed values over the n locations can be conducted based on the standardized Moran I.

Table 1 a, b displays the values of the Moran's I statistic for the numbers of TCM providers and Western hospitals by district for the 1910s, 1920s and 1930s. Table 2a displays the values of the Moran's I statistic for the number of TCM providers (with temple markets) by district for the 1910s and 1930s and b for the number of TCM providers (with guilds) by district for the 1910s and 1920s. This analysis is carried out using Spatial Statistics tools in ARC/GIS 9.3.

Table 5.1a. Moran's I statistics for the number of TCM providers in the 1910s, 1920s and 1930s.

Year	Moran's I	Z score	P-values
1910s	0.22	4.11	0.01
1920s	0.15	3.05	0.01
1930s	0.16	2.54	0.05

Table 5.1b. Moran's I statistics for the number of Western hospitals in 1914, 1929 and 1935.

Year	Moran's I	Z score	P-values

1914	0.06	1.04	Radom
1929	0.11	2.02	0.05
1935	0.31	4.8	0.01

Table 5.2a. Moran's I statistics for the number of TCM providers (with temple markets) in the 1910s and 1930s.

Year	Moran's I	Z score	P-values
1910s	0.2	3.71	0.01
1930s	0.16	2.53	0.05

Table 5.2b. Moran's I statistics for the number of TCM providers (with guilds) in the 1910s and 1920s.

Year	Moran's I	Z score	P-values
1910s	0.51	7.71	0.01
1920s	0.45	6.91	0.01

It appears that the numbers of TCM providers for each district are positively spatially autocorrelated because the statistics are significant with $p = 0.01$ for 1910s, 1920s and $p=0.05$ for 1930s. This result suggests that the distribution of TCM providers was by nature clustered over the whole period though the significance decreased in the 1930's. The numbers of Western hospitals for each district appeared to be random for 1914 but positively spatially autocorrelated for 1929 and 1935 because the statistics are significant with $p>0.1$ for 1910s, $p=0.05$ for 1920s and p=0.05 for 1930s. It can be observed that there was a trend from random to clustering in the distribution of Western hospitals over the republican period.

The Moran's I statistics are significant for TCM providers (with temple markets) with p=0.01 for 1910's and p=0.05 for 1930s. The Moran's I statistics are significant for TCM providers (with guilds) with p=0.01 for 1910s and p=0.01 for 1920's. These results suggest similar patterns to those observed by using the TCM data without temple markets and guilds.

5.4 Hotspot Analysis and Local Clustering

The hotspot analysis (Getis Getis-Ord Gi*) is a distance-based statistic that measures the proportion of a variable found within a given radius of a point, respective to the total sum of the variable in the study region. The statistic is defined for location *i* as

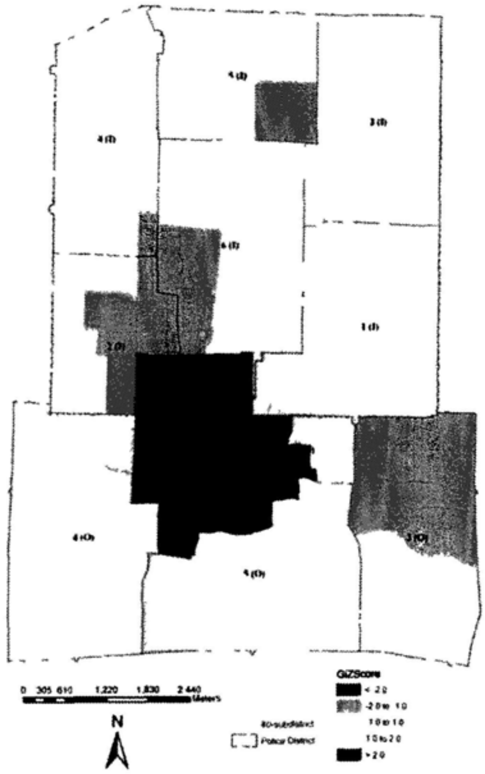
$$G_i(d) = \frac{\sum_{j=1}^{n} w_{ij}(d) x_j}{\sum_{j=1}^{n} x_j} \quad , j \neq i \qquad (5.2)$$

where x_j is the value of the observation at j , $w_{ij}(d)$ is the ij element of a binary weight matrix with ones for all sites within distance d of location i and zeros otherwise, and n is the number of observations. A significant and positive Gi indicates that the location i is surrounded by relatively high values while a significant and negative Gi indicates that the location i is surrounded by relatively low values. The G statistics is useful to reveal spatial agglomerative patterns with high-value clusters or low-value clusters. By being distance-based, it provides a flexible way of studying local spatial autocorrelation that works with positive variables that have a natural origin.

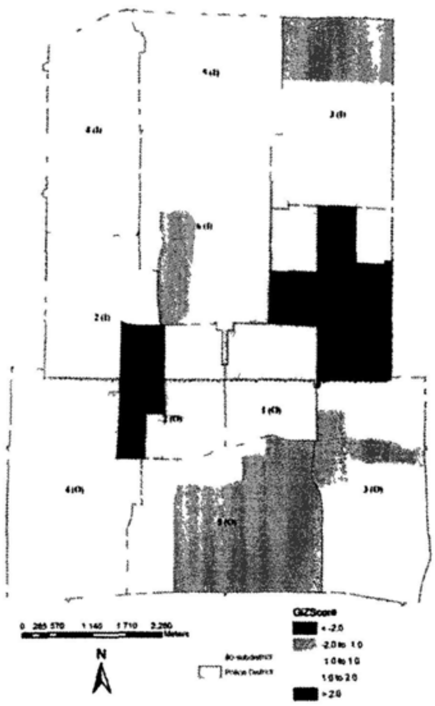
Different distance thresholds (i.e. 1000, 1500, 2000 and 2500 meters) are tested for the hotspot analysis and finally a fixed distance of 1500 meter is selected for analysis. The analytical results are displayed in fig.1-5. The red colour areas indicate presence of statistically significant hot-spots while the dark blue areas for statistically significant cold spots. For those areas in light blue, orange or yellow, the chance of them being a cluster is much less than hotspot and cold spot areas. This analyse is carried out using Spatial Statistics tools in ARC/GIS 9.3.

Spatial patterns of TCM and Western medical services in the 1910s

a


GiZScore
< -2.0
-2.0 to 1.0
1.0 to 1.0
1.0 to 2.0
> 2.0
Police District
0 305 610 1,220 1,830 2 440
Meters
N

b


GiZScore
< -2.0
-2.0 to 1.0
1.0 to 1.0
1.0 to 2.0
> 2.0
0 285 570 1 140 1 710 2,280
Meters
N

(O) = (Outer); (I) = (Inner) ; E.g.1 (I) = District 1(Inner)

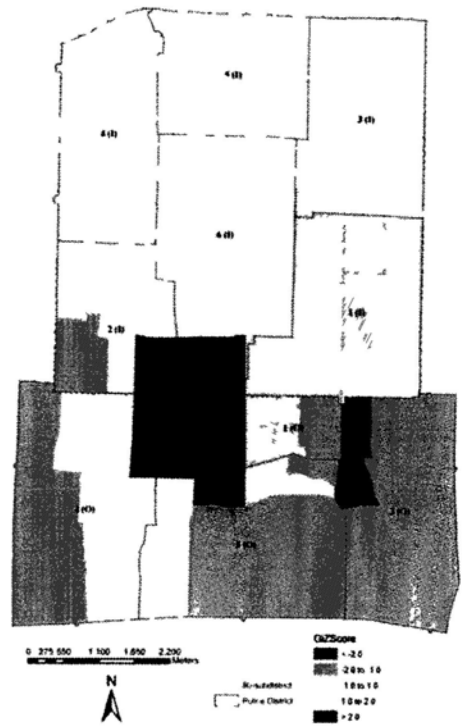
Fig.5.1a Hot-spot analysis for the number of TCM providers by district at 1500 m distance threshold in the 1910s b Hot-spot analysis for the number of Western hospitals by district at 1500 m distance threshold in 1914.

We note that for the TCM, one fifth (16 out of 80) of the Getis–Ord statistics are significant at the 5% level in the 1910s (16/80 are all positive). For Western medicine, less than one tenth (7 out of 80) of the Getis–Ord statistics are significant at the 5% level in 1914 (7/80 are all positive).

The hotspot analysis for TCM providers in the 1910s shows statistically significant hotspots mainly in district 2 (outer) where Tongrentang was located, district 1 (outer), district 5 (outer) and district 2 (inner). The hotspot analysis for Western hospitals in 1914 shows statistically significant hotspots mainly in district 1(inner), where Xiehe hospital was located, district 2 (inner) and district 4 (outer). There is a small region around Xijiaominxiang which is a hotspot for both TCM and Western medicine. In fact, the spatial patterns of medical services in the 1910s can be described by using a rough north-south split that South City had better TCM services while North city had better Western medical services.

Spatial patterns of TCM and Western medical services in the 1920s

a


GiZScore
0 275 550 1 100 1 650 2 200
Meters
N
Police District

b

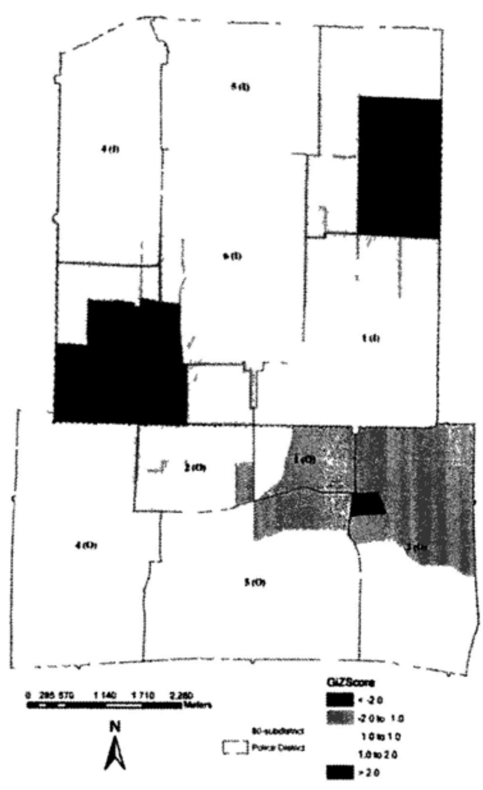

GiZScore
0 285 570 1 140 1 710 2 280
Meters
N
Police District

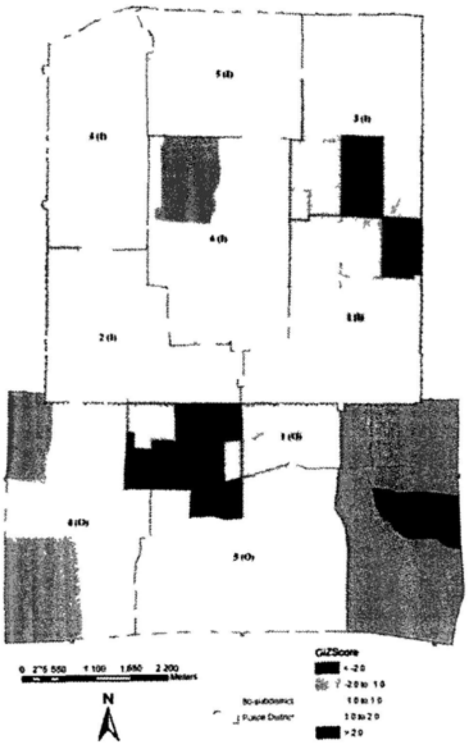
Fig.5.2 a Hot-spot analysis for the number of TCM providers by district at 1500 m distance threshold in the 1920s. b Hot-spot analysis for the number of Western hospitals by district at 1500 m distance threshold in 1929.

In the 1920s, less than one fifth (15 out of 80) of the Getis–Ord statistics are significant at the 5% level for the TCM (11/80 are positive and 4/80 are negative). For Western medicine, one tenth (8 out of 80) are significant (7/80 are positive and 1/80 is negative) at the 5% level in the 1929.

The hotspot analysis for TCM providers in the 1920s shows statistically significant hotspots in the same districts but shrinking and significant coldspots in district 3(outer). The hotspot analysis for Western hospitals in 1929 shows statistically significant hotspots in district 2(inner) and district 3(outer) and significant coldspots in district 3(outer). However, district 1(inner) became a random pattern.

Spatial patterns of TCM and Western medical services in the 1930s

a



b

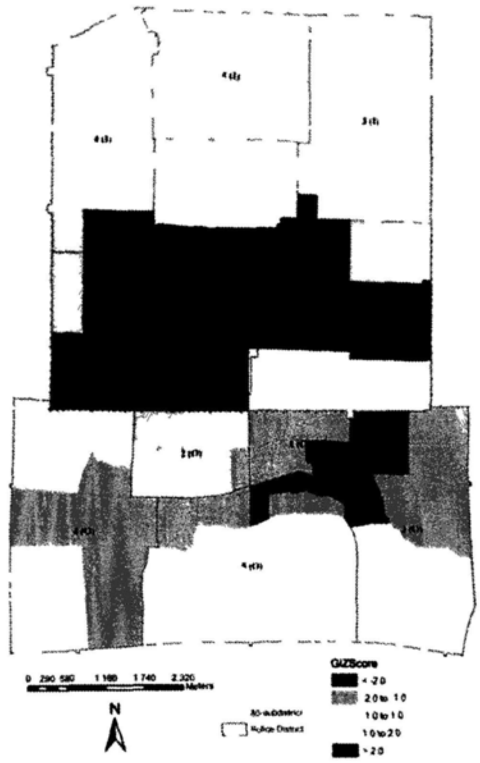


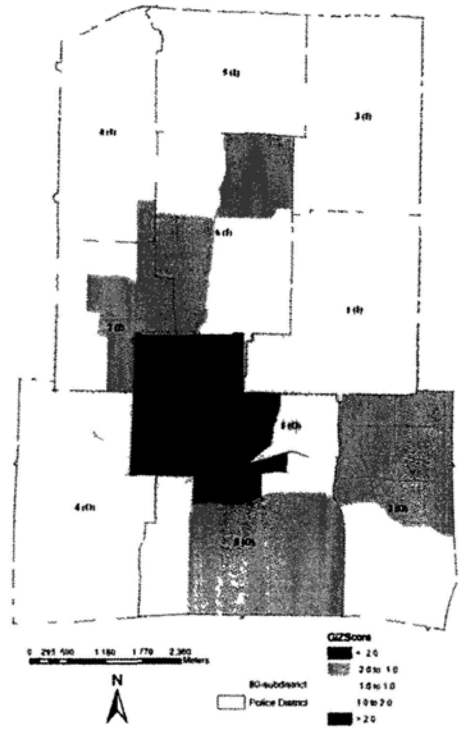
Fig.5.3a Hot-spot analysis for the number of TCM providers by district at 1500 m distance threshold in the 1930s and b Hot-spot analysis for the number of Western hospitals by district at 1500 m distance threshold in 1935.

In the 1930s, one eighth (10 out of 80) of the Getis–Ord statistics are significant at the 5% level in the 1930s for the TCM (9/80 are positive and 1/80 are negative). For Western medicine, almost one third (25 out of 80) are significant (15/80 are positive and 10/80 are negative) at the 5% level in 1935.

The hotspot analysis for TCM providers in the 1930s shows statistically significant hotspots in district 2 (outer), district 5 (outer), district 1(inner) and district 3 (inner) and significant hotspots in district 3(outer). The presence of hotspots in the North City has changed the South-North pattern for the TCM. The hotspot analysis for Western hospitals in the 1935 shows statistically significant hotspots spreading from the west to the east in the North City, including district 2(inner), district 6(inner) and district 1(inner), and significant coldspots in district 1(outer), district 3(outer) and district 5(outer). It appears that the South-North pattern for Western medicine becomes more significant.

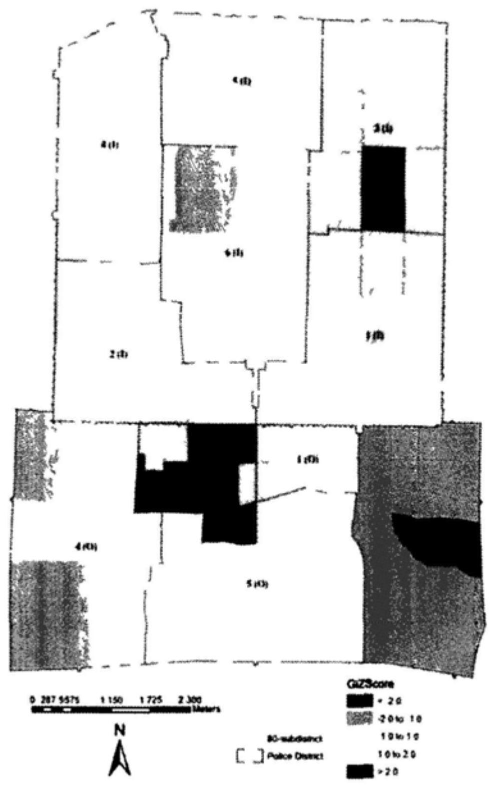
Validation of spatial patterns of TCM services for different periods

a



GiZScore
Police District
Meters
N

b



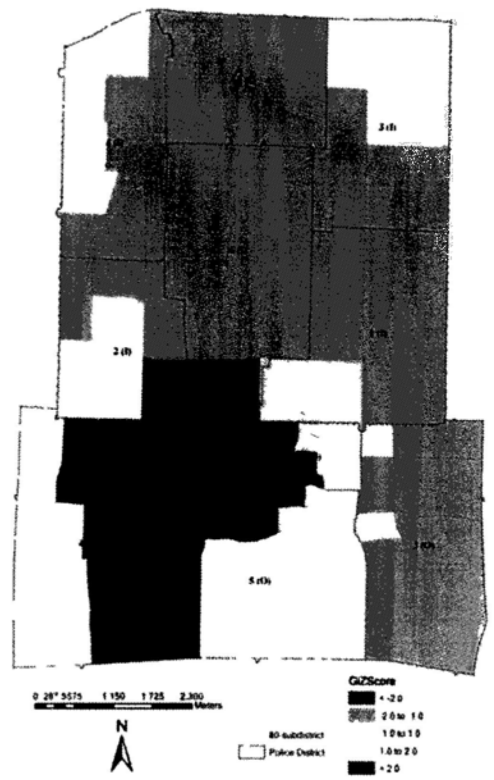
GiZScore
Police District
Meters
N

Fig.5.4a Hot-spot analysis for the number of TCM providers (including temple markets) by district at 1500 m distance threshold for the 1910s and b for the 1930s.

There are almost one fifth (14 out of 80) of the Getis–Ord statistics significant at the 5% level (14/80 are all positive) for the 1910s while one eighth (10 out of 80) for the 1930s (9/80 are positive and 1/80 is negative).

The hotspot analysis for TCM providers (with temple markets) in the 1910s shows statistically significant hotspots in district 2 (outer), district 1 (outer), district 5 (outer) and district 2 (inner). The hotspot analysis for TCM providers (with temple markets) in the 1930s shows statistically significant hotspots in district 2 (outer), district 5 (outer) and district 3(inner) and coldspot in district 3(outer). These patterns are similar to those observed by using the TCM data without temple markets (see fig6.1a and fig6.3a).

a


GiZScore
Meters
N
Police District

b

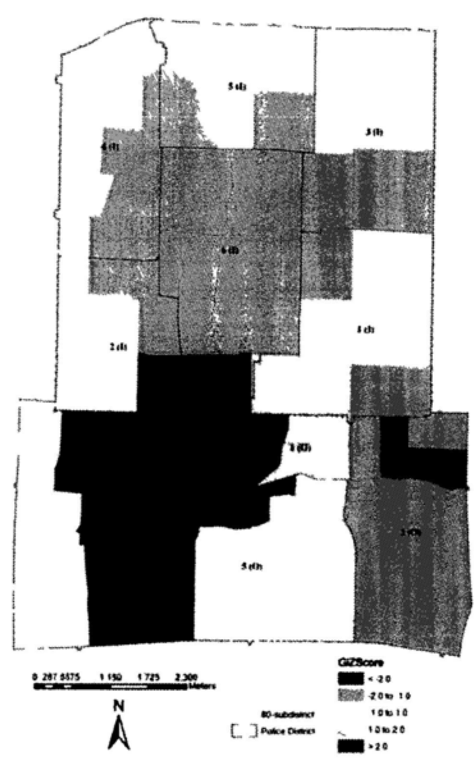

GiZScore
Meters
N
Police District

Fig.5.5a Hot-spot analysis for the number of TCM providers (including guilds) by district at 1500 m distance threshold for the 1910s and b for the 1920s.

There are more than one forth (23 out of 80) of the Getis–Ord statistics significant at the 5% level (23/80 are all positive) for the 1910s while less than one third (26 out of 80) for the 1920s (21/80 are positive and 5/80 are negative).

The hotspot analysis for TCM providers (with guilds) in the 1910s shows statistically significant hotspots in district 2 (outer), district 1 (outer), district 4 (outer) district 5 (outer) and district 2 (inner). The hotspot analysis for TCM providers (with guilds) in the 1920s shows statistically significant hotspots in the same districts and coldspots in district 3 (outer). These patterns are similar to those observed by using the TCM data without guilds (see fig.6.1a and fig6.2a).

5.5 Summary

We have applied Moran's I statistics and hotspot analysis to analyze the global and local spatial autocorrelation of TCM and Western medical services in the 1910s, 1920s and 1930s. The major findings are:

a. The spatial distribution of TCM providers were clustered over the whole period, but the significance decreased in the 1930s.

b. The spatial distribution of Western hospitals appeared to be random in 1914 but became clustered in 1929 and 1935.

c. The spatial patterns of medical services can be described by using a rough north-south split. The South City had better TCM services while North city had better Western medical services in the 1910s and 1920s.

d. The north-south pattern for TCM was changed due to the presence of hotspots in the North City in the 1930s.

f. However, the north-south pattern for Western medicine was enhanced in 1935.

g. The analytical results of incorporating temple market and guild data suggest that the spatial patterns of TCM for the three periods illustrated above are relatively stable and reliable, and could be used to investigate some aspects of the trend of medical service development in republican period.

CHAPTER 6: TCM, WESTERN MEDICAL SERVICES AND URBAN TRAFFIC

6.1. Introduction

This chapter attempts to present the spatial patterns of TCM and Western medical services in Beijing in the 1930s and test them against the pattern of urban traffic. In section 2, we will describe the data. Section 3 presents the two step floating catchment area method and the findings of patterns of spatial accessibility to traditional Chinese and Western medical services. Section 4 presents buffer analysis and the findings of the relations between the TCM, western medicine and the traffic. The last section is a summary of the findings.

6.2 Data Source

The road data come from the survey map of inner and outer cities of Beiping in 1937. There are several kinds of roads appearing on the 1937 map legend. These are hutong, asphalt, macadam, stone path, walkway, country road, lane and streetcar. The population data come from *The Statistical graph of registered residence of Beiping police department* published by Beiping Police Department in 1937, which contained statistical data about different kinds of household, female and male populations for the 11 police districts. The data on 1935 Western hospitals, 1935 drugstores, 1930 TCM doctors, 1936 temples and 1929 guilds have been introduced in the last chapter and we will not repeat here. The 1929 guilds are also included into the data on TCM providers in the 1930s in this analysis.

6.3 Measuring Spatial Accessibility by the Two-step Floating Catchment Area Method

The two-step FCA method was developed based on the early FCA. Luo (2004) applied this method to accessing areas with shortage of physicians in Illinois, US. He assumed a threshold travel distance of 15 miles for primary healthcare, a 15-mile circle is drawn around a residential tract as its catchment area. The circle with the same radius (i.e., catchment area) “floats” from the centroid of one tract to another, and the physician-to-population ratio within each tract defines the accessibility there. The underlying assumption is that services that fall within the catchment area are fully available to any resident within that catchment. However, not all physicians within the catchment are reachable by every resident in the catchment, and physicians on the periphery of the catchment may also serve nearby residents outside the catchment and thus may not be fully available to residents within the catchment.

A two step floating catchment area method was developed to overcome the above limitations. It repeats the process of “floating catchment” twice (once on physician locations and once on population locations), and thus is referred to as the “two-step FCA method”.

Step 1: For each hospital location j, search all population locations (k) that are within a threshold travel time d_0 from location j (i.e., catchment area j), and compute the physician to population ratio R_j within the catchment area:

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\le d_o\}} P_k} \tag{6.1}$$

where P_k is the population of tract k whose centroid falls within the catchment (i.e. $d_{kj} \le d_o$), S_j is the number of physicians at location j; and d_{kj} is the travel time between k and j.

Step 2: For each population location i, search all physician or sickbed locations (j) that are within the threshold travel time d_0 from location i (i.e., catchment area i), and sum up the physician to population ratios R_j at these locations:

$$A_i^F = \sum_{j\in\{d_{ij}\le d_o\}} R_j = \sum_{j\in\{d_{ij}\le d_o\}} \frac{S_j}{\sum_{k\in\{d_{kj}\le d_o\}} P_k} \tag{6.2}$$

where A_i^F represents the accessibility at resident location i based on the two-step FCA method, R_j is the physician-to-population ratio at physician location j whose centroid falls within the catchment centered at i (i.e., $d_{ij} \le d_o$), and d_{ij} is the travel time between i and j. The threshold time is set at 30 minutes in this study. A larger value of A_i^F represents a better spatial accessibility at resident location i.

One important task of implementing the healthcare accessibility measure is to estimate travel times between population and physician locations. The vehicular speeds need to be determined according to the historical context of Republican Beijing. During republican period, Beijing's traffic condition had been greatly improved due to the efforts made by the municipal government. While the streetcar was the major public transport, the rickshaw can be regarded as the predominant private vehicle and they carried the city's traffic together (Wang 2000; Du 2004). Concerning the carrying capabilities of these two kinds of vehicles, the "Far East Times" once made a comparison. It was estimated that the speed of a typical streetcar was 8.8 miles per hour compared with the speed of the rickshaw being 6 miles per hour (Wang 2003). Because streetcars could only go on roads with macadam or asphalt, we assumed both speeds were calculated based on relatively high quality roads (i.e. macadam). Table 1 shows the rickshaw speed estimation. The roads were classified into three levels. The higher the level, the faster the rickshaw's speed. Every level down will reduce 10% of velocity. The country roads and lanes are not included in this table because it is assumed that the rickshaw men would not choose those roads to go when they were running. Travel time between any pair of population and physician locations is estimated by using the Arc/Info network analysis module.

Table 6.1: Rickshaw travel speed estimation

Level	Road category	Speed (mile per hour)	Speed (meter per minute)
1	asphalt	6.6	177
2	macadam, stone path, hutong	6	161
3	walkway	5.4	145

The method can be implemented in ArcGIS 9.3 by the following procedures using a series of "join" and "sum" functions (see Fig.6.1 the case of Western hospitals).

(1) A matrix of travel times between physician location and population location is computed. The table (say, named Dis_30min) only includes those trips within the threshold time (e.g., 30 min) by setting a search radius in the network travel time computation command.

(2) Tables of physicians (say, hospital) and population (say, district) are then "joined" to the table Dis_30min by using hospital ID and district ID respectively.

(3) Based on the updated Dis_30min, a new table (say, RbyDoc) is generated by "summing" population by physician locations and computing an initial physician-to-population ratio for each physician location (indicating its physician availability).

(4) The updated table RbyDoc is "joined" to the table Dis_30min by using hospital ID

(5) Based on the updated Dis_30min, physician-to-population ratios are "summed" by population locations , generating a new table (say,RbyDis).

(6) Finally, the table RbyDis is "joined" to the population table by using district ID for mapping and analysis.

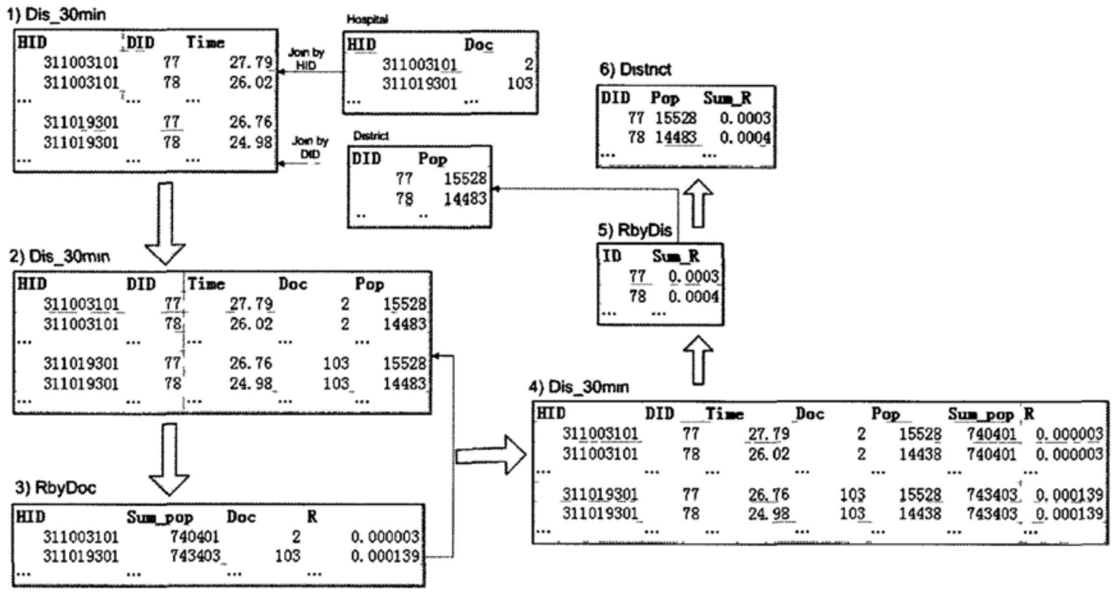


Fig.6.1 Flowchart of implementing the two-step FCA method

Fig.6.2 and Fig.6.3 show the variation of spatial accessibility to traditional Chinese and Western medical services measured by the two-step FCA method using a 30-min threshold time. Two observations can be made from these two figures:

(1) For traditional Chinese medical services, areas with higher accessibility scores (better spatial access) are concentrated in the central areas, e.g. district 6 (inner), district 1 (inner), district 2 (inner), district 1 (outer) and district 2 (outer) whereas areas with lower accessibility scores (poorer spatial access) are mostly in the South City, e.g. district 3(outer) and district 5(outer).

(2) For Western medical services, there is a clear spatial distinction with higher accessibility scores (better spatial access) in the North City and lower ones (poorer spatial access) in the South City. Within the North City, district 1 (outer) and district 2 (outer) have relatively higher accessibility scores than the other districts.

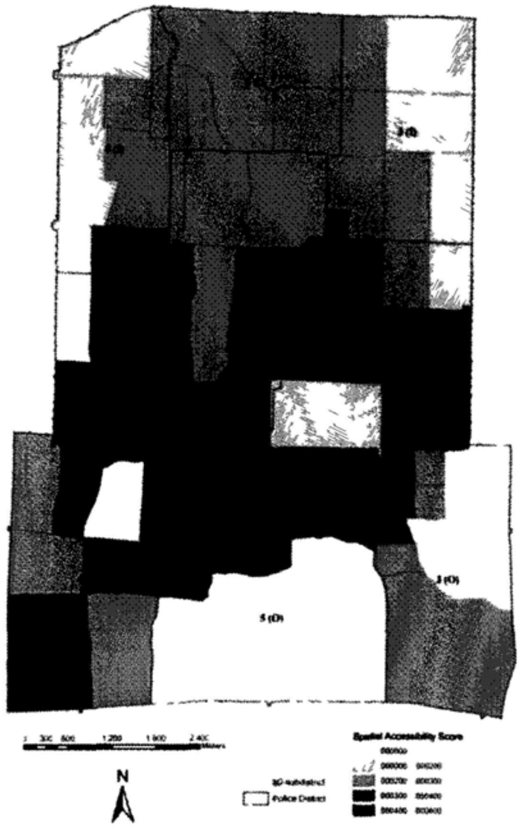


Fig.6.2 Spatial accessibility to TCM doctors in Republican Beijing.

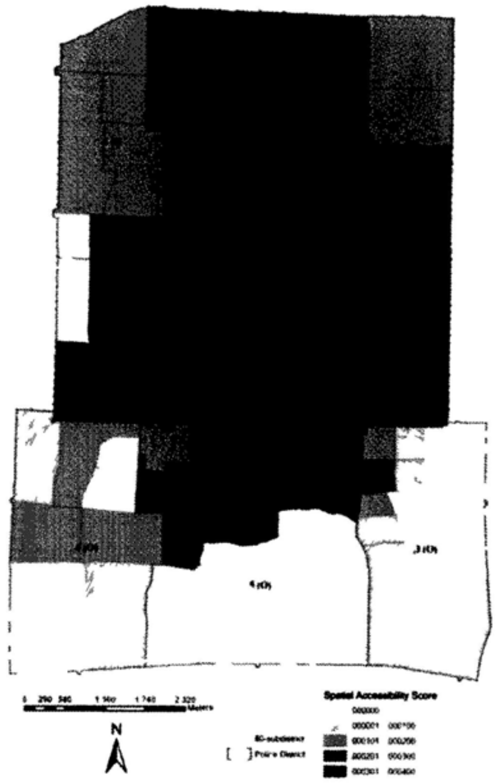
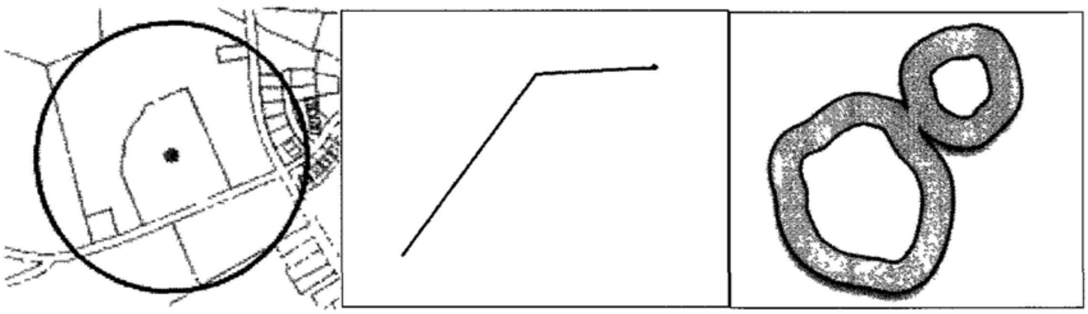


Fig.6.3 Spatial accessibility to Western hospitals in Republican Beijing.

6.4 Measuring Proximity by the Buffer Analysis

Buffer analysis is a common type of analysis with GIS, which is used for assessing proximity within a certain distance to a point, line, or area feature. The resulting buffer is a new polygon, which can be used in queries to determine which entities occur either within or outside the defined buffer zone. Figure 6.4 shows typical examples of point, line and area buffers. For instance, point buffers can identify the area around a contaminated well, line buffers can track exposure along a railroad line carrying hazardous materials and areal buffers can be computed around large Superfund sites.



a. Point buffer b. Line buffer c. Area buffer

Fig6.4 Examples of point, line and area buffers

In the case of buffer analysis around different kinds of roads, the buffer is drawn at a pre-defined distance, the TCM providers and Western hospitals are identified that are within the area in the buffer, and information about the numbers of TCM providers and Western hospitals in the buffer areas are used to examine the relationships between traditional Chinese, western medicine and the traffic. The roads are divided into four levels: asphalt for the first level, macadam or stone path for the second level, walkway for the third level and country road, lane for the fourth level. The streetcar is also included in the analysis for comparison purposes.

In this analysis, a series of distances are tested for the selection of optimal distance. For our purpose, we have two criteria for this selection: a) the shorter the distance, the better the distance; b) the buffer based on the distance should contain relatively higher percentages of TCM provider and Western hospital in the buffer area. The buffer analysis is conducted at different distances and the percentages of TCM provider and Western hospital in the buffers are calculated. Table 6.2 shows the analytical results for the streetcar. 500 m is regarded as the optimal distance.

Table 6.2 Results of buffer analysis for the streetcar at different distances

Distance	Percentage (TCM)	Percentage (Western medicine)
250 m	33%	3%
500 m	58%	79%
750 m	83%	94%
1000 m	92%	97%

Fig.6.5 and fig.6.6 illustrate 500 m buffers calculated for the streetcar for TCM providers and Western hospitals respectively. The results of the buffer analysis are recorded in table 6.3. One can see the variation in the relationships between Traditional Chinese and Western medical services and the traffic. For the Western medicine, the higher level the road, the larger the number of Western hospitals. The number of Western hospitals is the highest for asphalt (78), followed by macadam, stone path (57), walkway (30), and country road, lane (8). The number of Western hospitals is 74 for the streetcar. However, this is the case for TCM. The number of TCM providers is the highest for macadam, stone path (854), followed by asphalt (680), walkway (129), and country road, lane (125). The number of TCM providers is 639 for the streetcar.

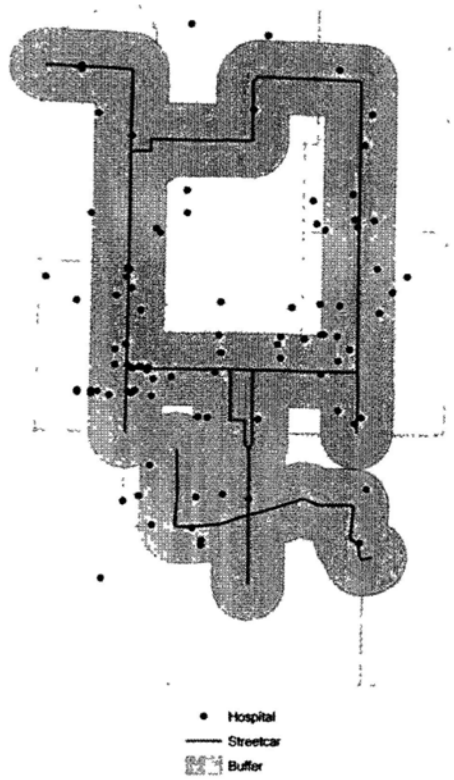


Fig.6.5 Western hospitals and 500-meter buffers for the streetcar

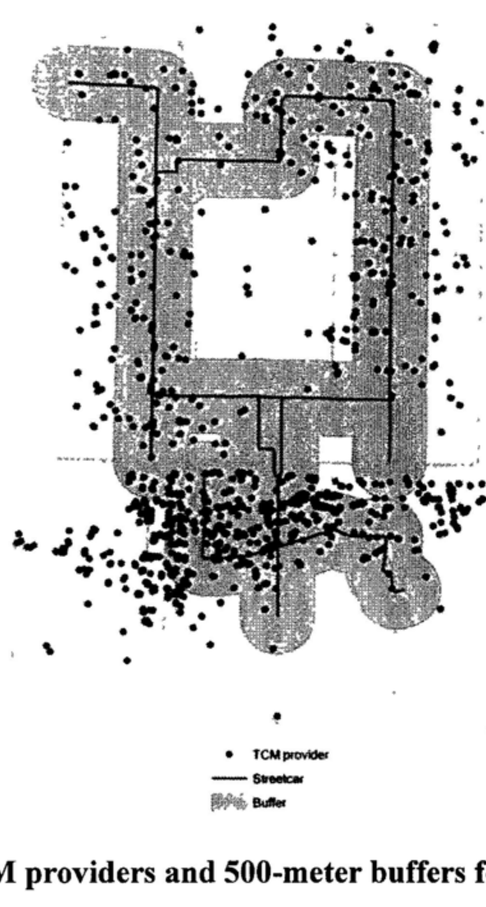


Fig.6.6 TCM providers and 500-meter buffers for the streetcar

Table 6.3 Numbers of Western hospitals and TCM providers inside 500-meter buffers for roads of different levels

Level	Road Category	Number of TCM providers	Number of Western hospitals
0	streetcar	639	74
1	asphalt	680	78
2	macadam, stone path,	854	57
3	walkway	129	30
4	country road, lane	125	8

6.5 Summary

We have applied the two-step FCA method and buffer analysis to measure the spatial accessibility to TCM and Western medical services and their relationships with the urban traffic.

The major findings are:

a. The central areas had better spatial access to traditional Chinese medical services.

b. The North City had better spatial access to Western medical services than the South City.

c. The urban traffic had great statistical impact on the presence of Western hospitals. The better the road, the more Western hospitals.

d. There was no strong relationship between TCM providers and the urban traffic.

These findings can be further examined against other spatial patterns derived from the dataset, for instance, how these patterns can be related to the patterns of population density, poverty, markets, religious organization and law enforcement, for example.

CHAPTER 7: SPATIAL VARIATIONS OF TCM AND WESTERN MEDICAL SERVICES

7.1 Introduction

This chapter attempts to test the spatial patterns of medical services against variables like population, temples, churches, industry-commerce, taps, lawyers, schools, poverty, toilets, lawsuits and soup-kitchens in Beijing in the 1930s. In section 2, we will describe the data. Section 3 briefly reviews the methodology of geographically weighted regression (GWR), the spatial statistical tool used in this chapter. Section 4 presents the findings of the relationship between TCM services and other variables. Section 5 presents the findings of the relationship between Western medical services and other variables. Section 6 presents the results of statistical testing of spatial variations of TCM and Western medical services. The last section is a summary of these findings.

7.2 Data Source

We used the locations and distributions of TCM providers, Western hospitals, population, temples, churches, industrial-commercial organizations, taps, lawyers and schools to represent the spatial patterns of TCM, Western medical services, population, temple, church, industry-commerce, tap, lawyer and school.

The data on TCM providers in the 1930s, 1935 Western hospitals and 1937 population have been introduced in the last two chapters. The 1936 (576 entries) temple data are derived from *The Historical Materials of Temples in Beijing* compiled by Beijing Municipal Archive in 1997. The industrial-commercial organization data (3191 entries) come from *A Summery of Commerce and Industry in Beiping* published by Beijing Municipal Bureau of Social Affairs in 1932, which provided general information about commercial and industrial organizations. The tap data come from the 1937 map which identifies the locations of the taps. The lawyer data (218 entries) are derived from *Archive of Roll of Lawyers Association Members* with its archive no. J65-3-545, J65-3-546 and J65-3-547, which contains detailed information about the lawyers. We only utilize the data on 1927 to 1932, the closest five years to our study period. The locations are based on the layers' home addresses. It is supposed that many of them would work at home. The school data (148 entries) are derived from *Archives J004-001-00362 and J004-004-00396* in 1937. These archives provide information about the popular education such as public schools or continual schools.

The poverty data come from *Beiping City Government Public Security Bureau Business Report from 1933 to 1934,* which contains information about the poor. The toilet data come from *Beiping City Government Health Board Business Report* in 1933, which was the survey of the toilets in the city. The lawsuit data come from *Archives J181-20-13300 and J181-20-13301,* which provides detailed information about different kinds of cases. The soup-kitchen data (9 entries) are derived from *Archive J2-7-182*, which contains information about the soup-kitchens in 1937. The data on poverty, toilets and lawsuits are all based on the 11 police districts and there are only a few entries for the soup-kitchen data. These data are not involved in the GWR analysis but incorporated in the discussion section to further investigate the spatial variations of TCM and Western medical services.

7.3 GWR Approach

GWR is a technique that extends an ordinary linear regression (OLR) model by allowing local variations in rates of changes. The coefficients in the extended model are specific to location i rather than assumed to be constant. An ordinary linear regression model can be expressed as:

$$Y_i = \beta_0 + \sum_k \beta_k x_{ik} + \varepsilon_i \qquad i=1,\ldots,n \qquad (7.1)$$

where Y_i is the estimated value of the dependent variable for observation i, β_0 is the intercept, β_k is the parameter estimate for variable k, x_{ik} is the value of the k^{th} variable for i, and ε_i is the error term.

GWR extends the ordinary linear regression model by allowing the parameters to be estimated by a weighted least squares procedure. GWR equation can be expressed as:

$$\hat{Y}_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i) x_{ik} + \varepsilon_i \qquad (7.2)$$

where (u_i, v_i) captures the coordinate location of i (Fotheringham 1997a). The assumption is that observations nearby one another have a greater influence on one another's parameter estimates than observations further apart. The weight assigned to each observation is based on a distance decay function centred on observation *i*. The distance decay function usually takes the following forms:

$$w_j(u_i,v_i) = \exp\left[-\left(\frac{d_{ij}}{h}\right)^2\right], j = 1,2,\ldots,n \tag{7.3}$$

$$w_j(u_i,v_i) = \begin{Bmatrix} \left[1-\left(\frac{d_{ij}}{h}\right)^2\right]^2, d_{ij} \leq h; j = 1,2,\ldots,n \\ 0, d_{ij} > h; j = 1,2,\ldots,n \end{Bmatrix} \tag{7.4}$$

Where d_{ij} is the distance between location (u_i,v_i) and location (u_j,v_j), h is the bandwidth which can be chosen by using an algorithm that seeks to minimize a cross-validation score, given as

$$CV = \sum_{i=1}^{n}(Y_i - \hat{Y}_{i\neq i})^2 \tag{7.5}$$

where n is the number of observations, and observation *i* is omitted from the calculation so that in areas of sparse observations the model is not calibrated solely on *i*. Alternatively, the bandwidth may be chosen by minimizing the Akaike Information Criteria (AIC) score, give as

$$AIC_c = 2n\log_e(\hat{\sigma}) + n\log_e(2\pi) + n\left\{\frac{n+tr(S)}{n-2-tr(S)}\right\} \tag{7.6}$$

where *tr(S)* is the trace of the hat matrix. A fixed bandwidth for every observation can be chosen flexibly by the users.

7.4 Spatial Variation of TCM Services

The number of TCM providers for each district is the dependant variable, and the number of Western hospitals, population, as well as numbers of temples, churches, industrial-commercial organizations, taps and lawyers for each district are independent variables.

To begin with, the technique of stepwise regression is used to select the important factors affecting TCM services. The GWR model to be estimated here only includes Western hospitals, temples, industrial-commercial organizations, taps and lawyers.

Before conducting GWR, a global regression (i.e. OLS), is carried out to measure the general relationships between TCM providers and the other factors. The results of global regression model shown in Table 7.1 suggest that TCM providers are positively related to temples, industrial-commercial organizations, taps and lawyers while negatively related to Western hospitals. The Industry-commerce and lawyer factors are more significant than the other factors for TCM services. The R-square of the global model is 36%, adjusted R-square is 31% and AIC is 637. It is clear there are some factors that are not captured adequately by the global model. The results of the GWR are reported. It is well known that GWR model contains several sets of mappable statistics which denote local relationships. The spatial distributions of parameter estimates are shown in Figs. 7.1-7. Based on the spatial distributions of the parameter estimates, there appears to be significant variations in the relationships between TCM providers and Western hospitals, temples, industrial-commercial organizations, taps and lawyers. The R-square of the GWR model is 67%, adjusted R-square is 57% and AICc is 614.

Table 7.1 Results of global regression model

Variable	Coef	StdError	t_Stat	Prob
Intercept	3.38677	2.71220	1.24872	0.21570
Western hospital	-1.38405	0.93395	-1.48194	0.14261
Temple	0.19867	0.28709	0.69202	0.49109
Industry-commerce	0.12239	0.04691	2.60909	0.01098
Tap	0.73244	0.38728	1.89122	0.06251
Lawyer	1.33098	0.52850	2.51841	0.01395

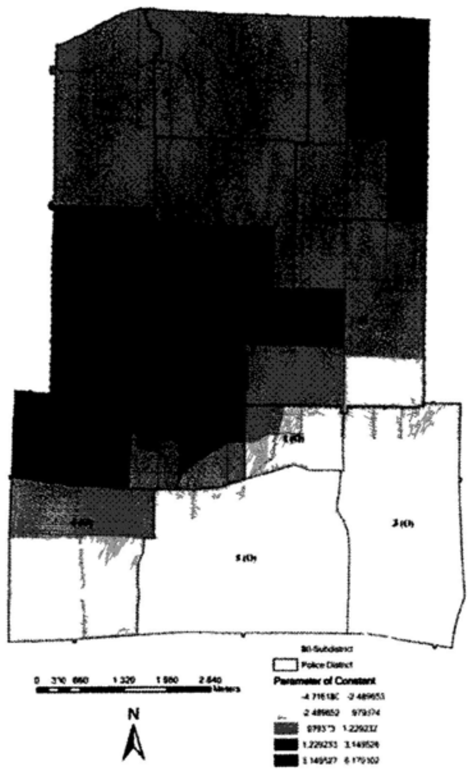


Fig.7.1 Spatial distribution of the regression constant

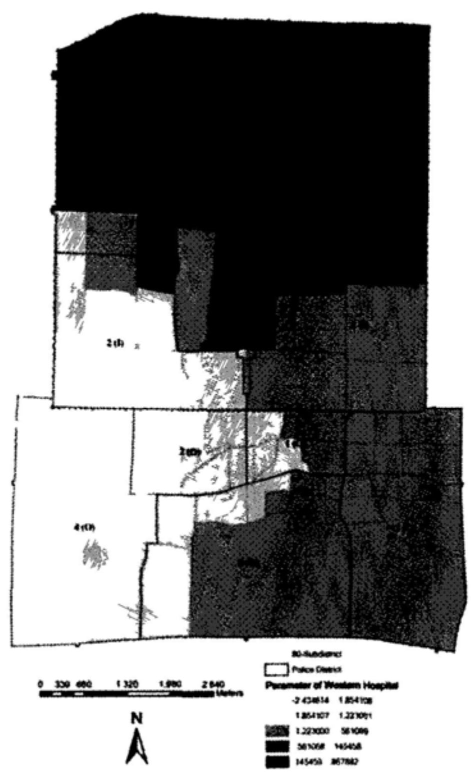


Fig.7.2 Spatial distribution of the Western hospital parameter

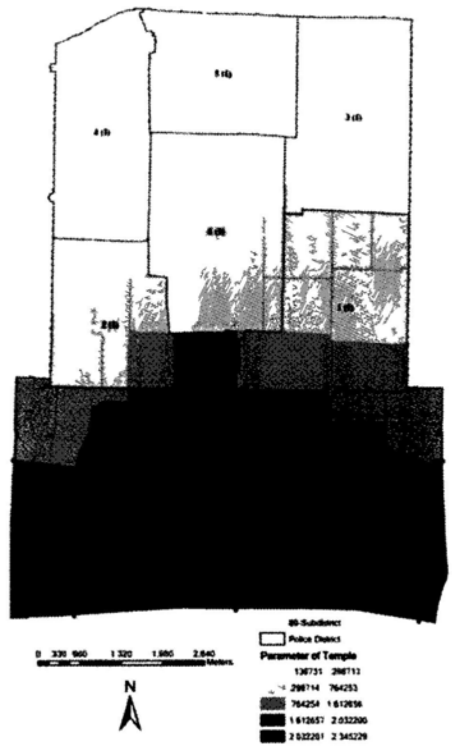


Fig.7.3 Spatial distribution of the Temple parameter

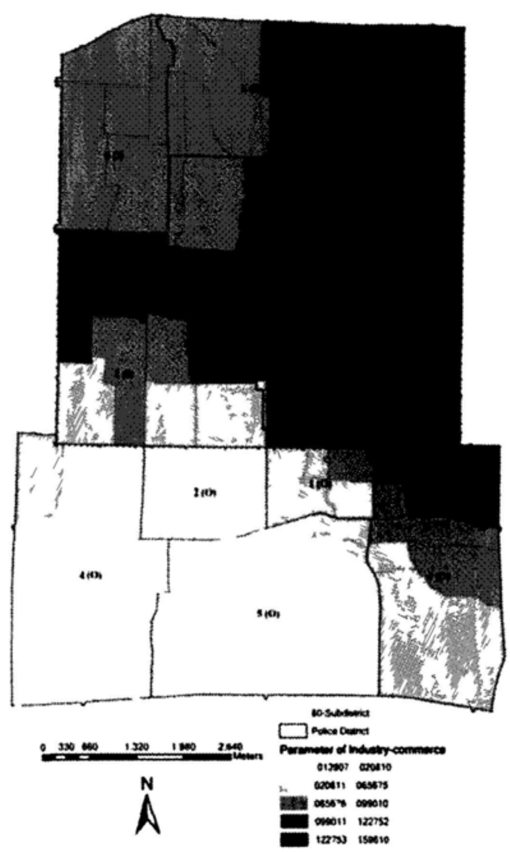


Fig.7.4 Spatial distribution of the industrial-commercial organization parameter

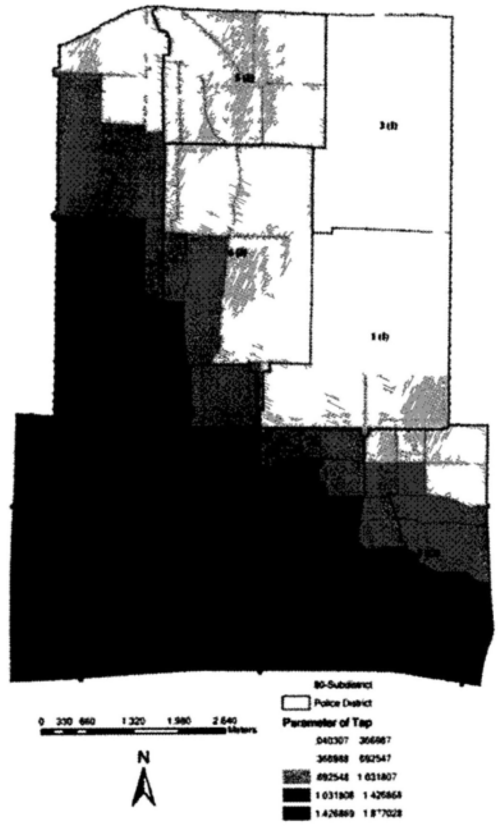


Fig.7.5 Spatial distribution of the tap parameter

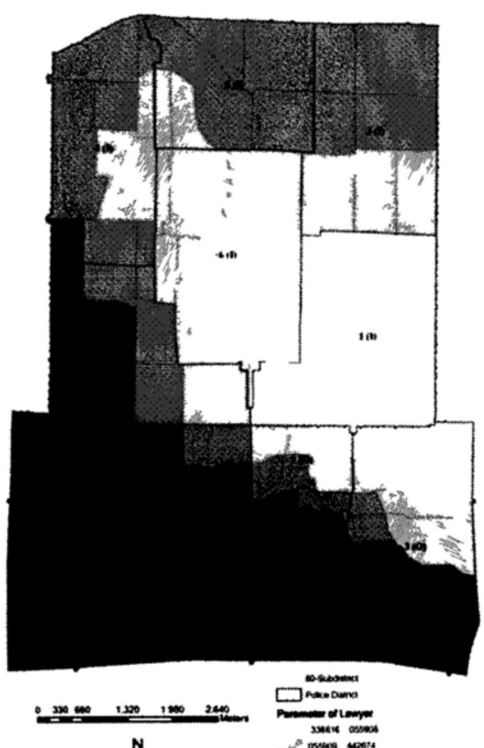


Fig.7.6 Spatial distribution of the lawyer parameter

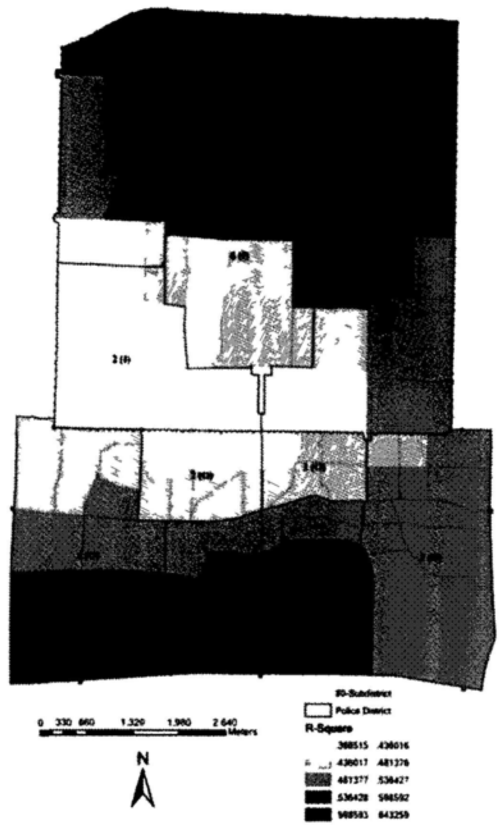


Fig.7.7 Spatial distribution of the R-square value

Figure 7.1 shows the spatial distribution of the intercept term. The intercept term or constant parameter refers to the fundamental level of TCM services excluding the effects of all factors. The areas with greatest parameter estimates predominately are situated in the western areas such as district 2 (inner), district 6 (inner), district 2 (outer) and district 4 (outer). It means if other factors are equal, these areas had a higher basic level of TCM services than other parts of the city.

The spatial distribution of Western hospital parameter is shown in Fig.7.2. The Western hospitals had the greatest effect on TCM providers in the northern areas of the North City. There are four groups with negative parameter estimates in Fig. 7.2, this indicates that the Western hospital factor had a negative effect on TCM services in most areas of Beijing. It is understandable that Western medicine would have a negative effect on TCM.

Figure 7.3 shows the spatial distribution of the temple parameter. There is a clear spatial distinction with higher parameter estimates in the South city and lower ones in the North city. It means the temple factor had greater effect on TCM services in the South City than in the North City. There are four groups with positive parameter estimates in Fig. 7.3, which indicates that the temple factor had a positive effect on TCM services in most areas of Beijing. The parameter estimate of temple factor in the global model is 0.19867 belonging to the first group in Fig.7.3. Thus, the global model only represents a few areas in the North City.

The spatial distribution of the industrial-commercial organization parameter in Fig. 7.4 shows a spatial pattern different from that of the temple parameter. The industrial-commercial organization factor had greater effect on TCM services in the North City than in the South City. The areas with the greatest parameter estimates largely laid in the eastern areas such as district 1(inner), district 3 (inner) and district 6 (inner).

The spatial distribution of the tap parameter is shown in Fig. 7.5. It is spatially distinctive and reflected by a clear distinction between southeast and northwest, with higher parameter estimations in the western end and lower ones in the eastern side. All the parameter estimations are positive, which indicates that the tap factor, which reflects some aspects of the city's public health, had a positive effect on TCM within Beijing.

The spatial distribution of the lawyer parameter in Fig. 7.6 is very similar to that of the tap parameter in Fig. 7.5. It is apparent that the lawyer factor was more important to TCM providers in the southwest such as district 4 (outer) and district 5 (outer).

The spatial distribution of goodness-of-fit statistic, R-square parameter is shown in Fig. 7.7. The R-square value ranges from 0.368515 to 0.643259. As analyzed earlier, the R-square of the global model is 36%, which is between the minimum and the maximum values of R-square of GWR. It can be observed that the northern areas such as district 3 (inner), district 4 (inner) and district 5 (inner) have higher R-square values. This means the relationships between TCM providers and the selected variables are much better captured by GWR in the northern areas. However, the central areas such as some parts of district 1(inner), district 2(inner) and district 6(inner) have lower R-square values. This indicates that other factors might have played an important role in the TCM services in these areas, but are missing in the GWR model. This can be further studied when such data become available.

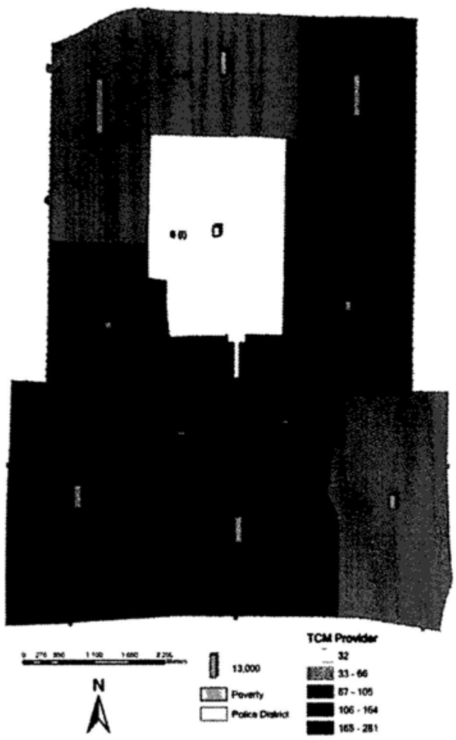


Fig.7.8 spatial patterns of TCM providers and poverty population.

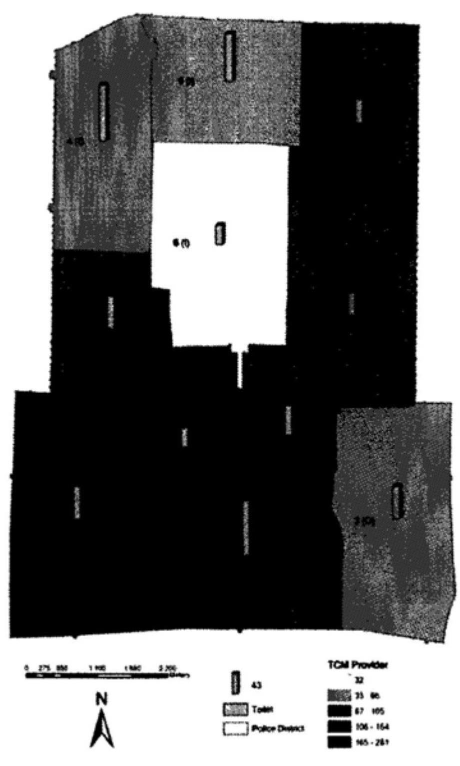


Fig.7.9 Spatial patterns of TCM providers and toilets.

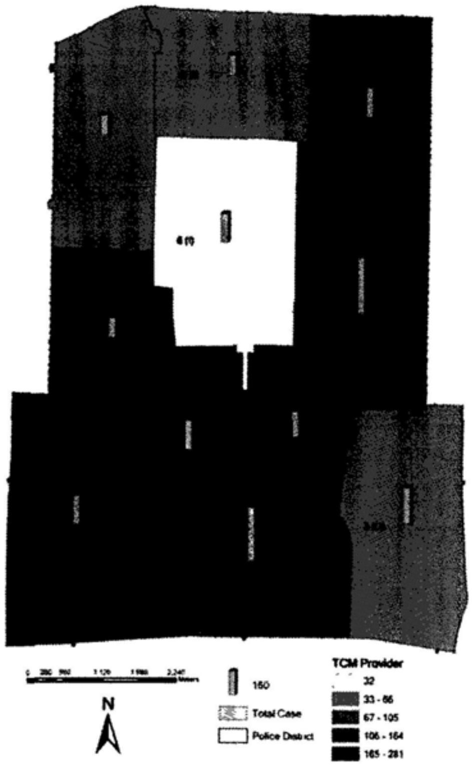


Fig. 7.10 spatial patterns of TCM providers and total lawsuits.

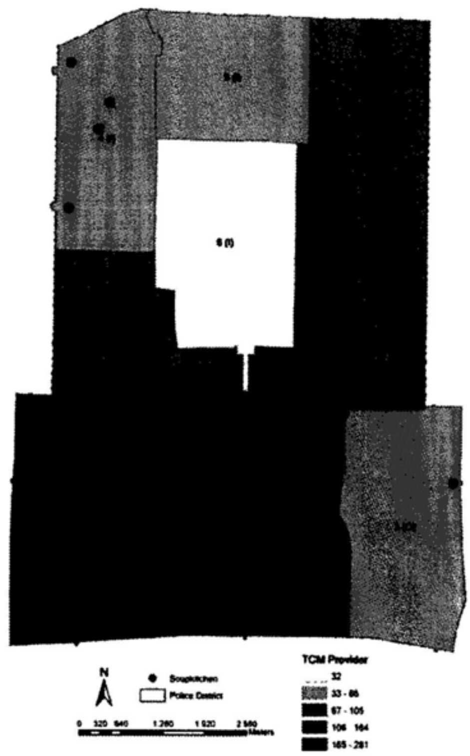


Fig. 7.11 spatial patterns of TCM providers and soup-kitchens.

Fig.7.8-11 shows the spatial patterns of TCM providers and poverty population, toilets, total number of different kinds of lawsuits and soup-kitchens based on the 11 police districts. Several observations can be made from these figures:

a) Districts with better TCM services had relatively smaller poverty population. e.g. district 1 (outer), district 2 (outer);

b) There were more toilets distributed in districts with poorer TCM services. e.g. district 4 (inner) and district 3 (outer);

c) There were more lawsuits in districts with poorer TCM services. e.g. district 1 (inner) and district 5 (outer);

d) Most of the soup-kitchens were distributed in districts with poorer TCM services, e.g. district 3 (inner) and district 4 (inner). Those districts with the best TCM services such as district 1 (outer) and district 2 (outer) didn't have any soup-kitchens at all.

7.5 Spatial Variation of Western Medical services

The number of Western hospitals for each district is the dependant variable, and the number of TCM providers, population, as well as numbers of temples, churches, industrial-commercial organizations, taps and lawyers for each district are independent variables.

The important factors affecting Western medical services are selected by the technique of stepwise regression. The GWR model includes temple, church, tap, lawyer factors.

Before conducting GWR, a global regression (i.e. OLS), is carried out to measure the general relationships between Western hospitals and other factors. The results of a global regression model is shown in Table 7.2 and suggest that Western hospitals are positively related to churches, taps and lawyers while negatively related to temples. The church and lawyer factors are more significant than the other factors for Western medical services. The R-square of the global model is 33%, adjusted R-square is 30% and AIC is 292. The results of the GWR are reported. Fig.7.12-17 show the spatial distributions of parameter estimates. The R-square of the GWR model is 39%, adjusted R-square is 31% and AICc is 296.

Table 7.2 Results of global regression model

Variable	Coef	StdError	t_Stat	Prob
Intercept	0.49668	0.31023	1.60100	0.11359
Temple	-0.05872	0.03306	-1.77592	0.07980
Church	0.61515	0.19239	3.19740	0.00203
Tap	0.05537	0.04079	1.35734	0.17875
Lawyer	0.21924	0.05681	3.85896	0.00024

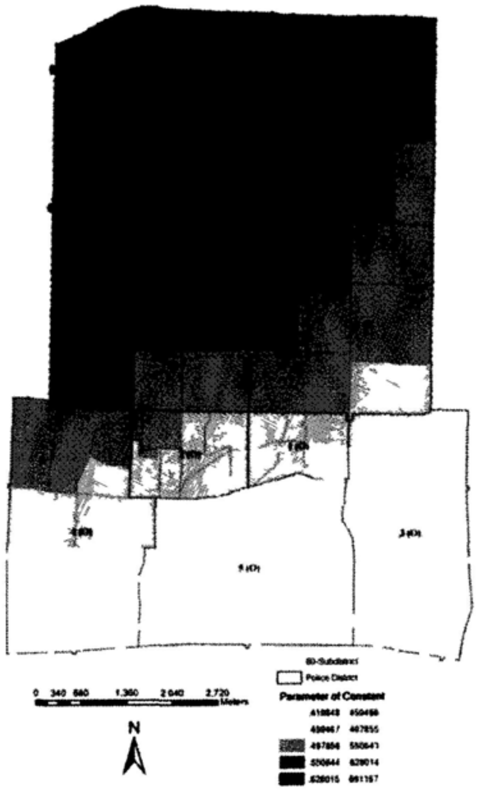


Fig.7.12 Spatial distribution of the regression constant

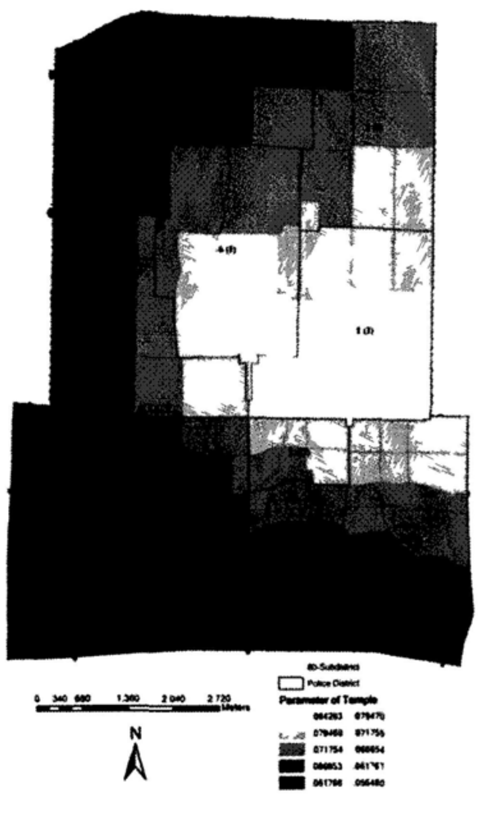


Fig.7.13 Spatial distribution of the temple parameter

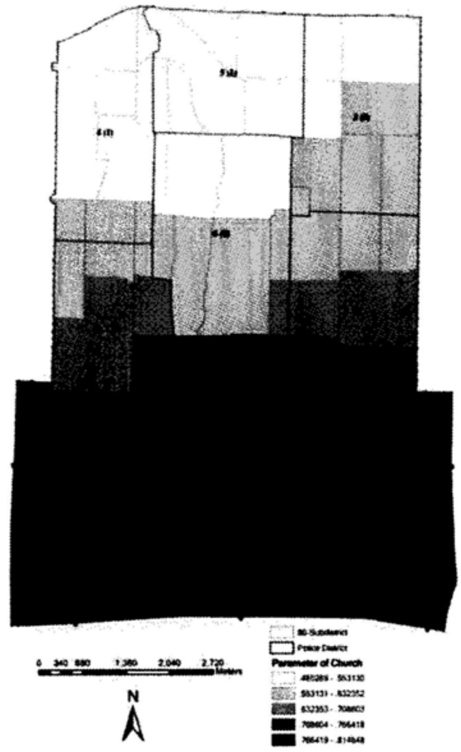


Fig.7.14 Spatial distribution of the church parameter

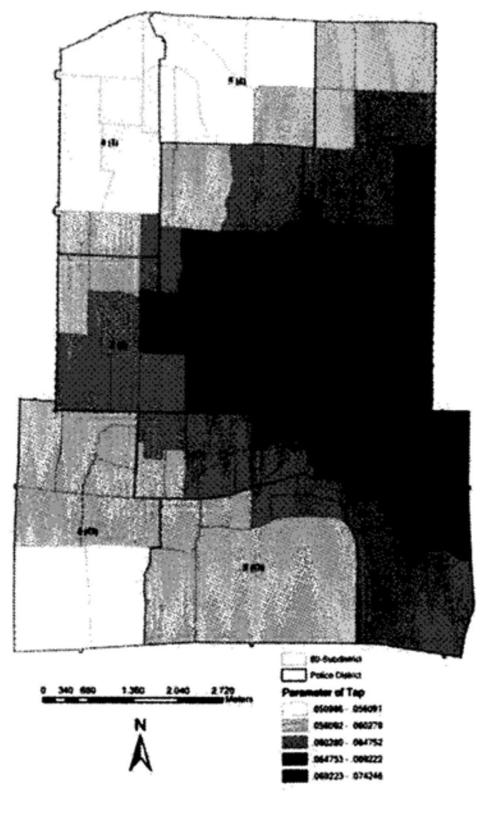


Fig.7.15 Spatial distribution of the tap parameter

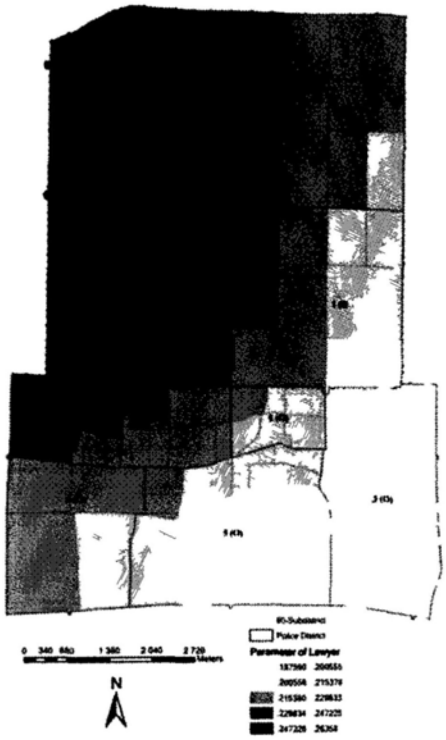


Fig.7.16 Spatial distribution of the lawyer parameter

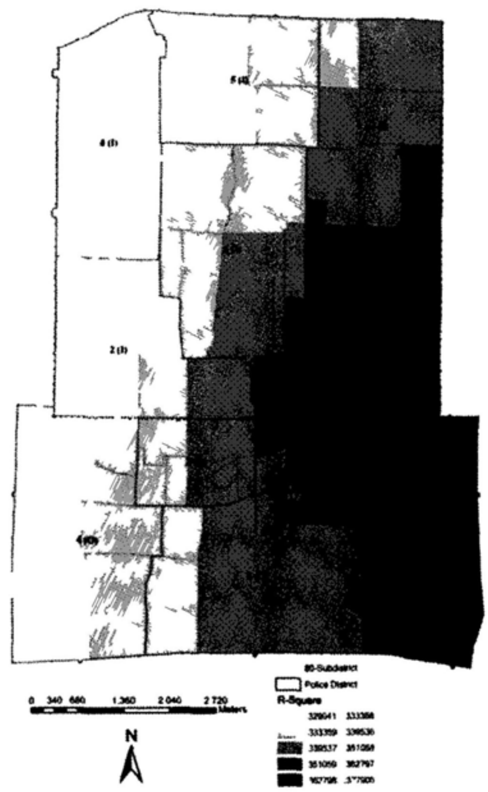


Fig.7.17 Spatial distribution of the R-square value

Fig.7.12 shows the spatial distribution of constant parameter. The constant parameter refers to the fundamental level of Western medical services excluding the effects of all factors. There is a clear spatial distinction with higher constant parameters in the North city and lower ones in the South city. It means the North city had a higher basic level of Western medical services than the South city.

The spatial distribution of temple parameter is shown in Fig. 7.13. All the parameter estimates are negative, which indicates that the temple factor had a negative effect on Western hospitals across Beijing city. The temples had the greatest effect on Western hospitals in some parts of district 4 (inner) and district 4 (outer), where there was a concentration of poor. Therefore, a poor population might have had a negative effect on the development of Western medical services in these areas.

The spatial distribution of the church parameter is shown in Fig. 7.14. It can be observed that the South City had greater parameter estimates while the North City had lower ones. It means churches had more important effect on Western hospitals in the South City than in the North City.

The spatial distribution of the tap parameter in Fig.7.15 shows a spatial pattern different from that of the church parameter. The eastern areas had greater parameter estimates while the western areas had lower ones. All the parameter estimates are positive, which indicates that taps had a positive effect on Western hospitals across Beijing city. The areas with the greatest parameter estimates largely laid in those districts around *Xiehe* hospital such as district 6 (inner) and district 1 (inner). This may provide some evidence that the city's public health work was enhanced by the development of Western medicine.

Fig. 7.16 shows the spatial distribution of the lawyer parameter. The lawyer variable had greater effect on Western hospitals in the North City than in the South City. It is clear that lawyers had the greatest effect on Western hospitals in the western areas of the North City.

The spatial distribution of R-square parameter is shown in Fig. 7.17. The R-square value ranges from 0.329041 to 0.377906, which are not much higher than the global R-square value. It seems that there are no significant variations in the relationships between Western hospitals and temples, churches, taps and lawyers. These results also indicate some important factors are missing in the GWR model in the analysis of Western medical services.

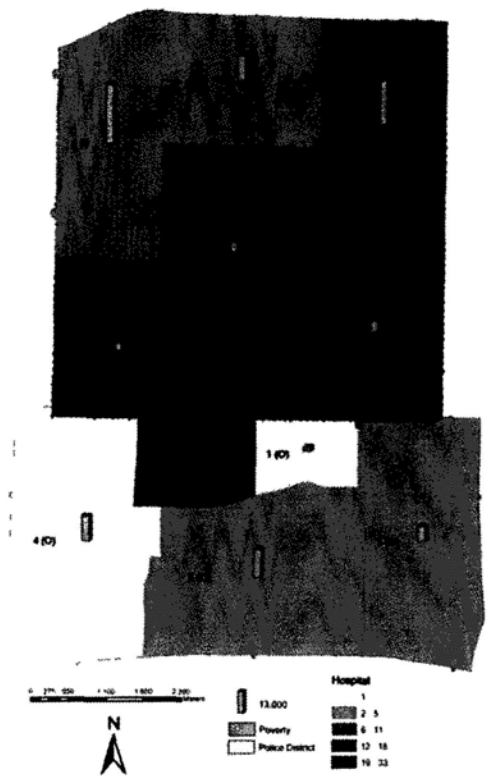


Fig.7.18 Spatial patterns of Western hospitals and poverty population.

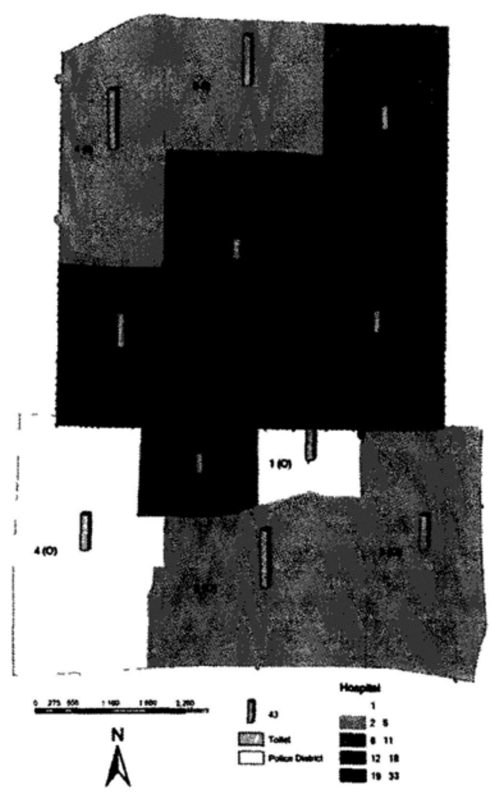


Fig. 7.19 Spatial patterns of Western hospitals and toilets.

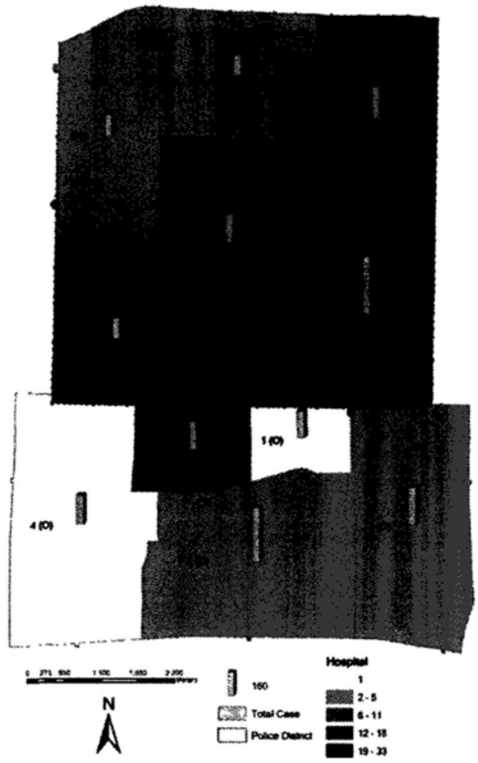


Fig.7.20 Spatial patterns of Western hospitals and total lawsuits.

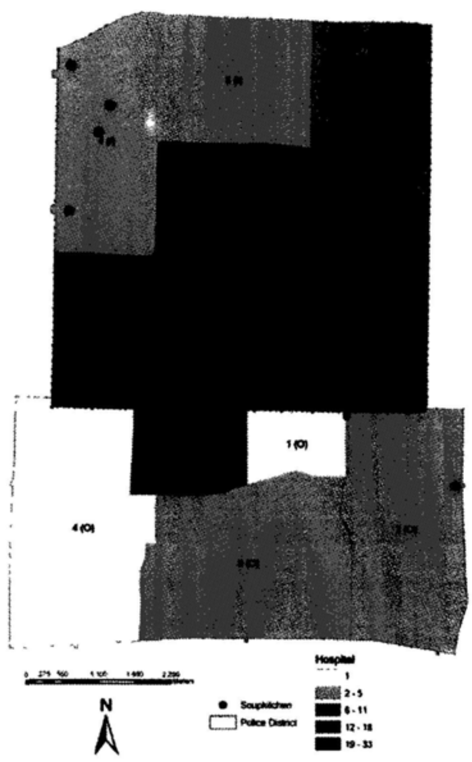


Fig.7.21 Spatial patterns of Western hospitals and soup-kitchens.

Fig.7.18-21 shows the spatial patterns of Western hospitals and poverty population, toilets, total number of different kinds of lawsuits and soup-kitchens based on the 11 police districts. Several observations can be made from these figures:

a) Districts with better Western medical services had relatively less poverty. e.g. district 1 (inner), district 2 (inner);

b) There were more toilets distributed in districts with poorer Western medical services. e.g. district 4 (inner) and district 5 (outer);

c) There were more lawsuits in districts with poorer Western medical services. e.g. district 3 (outer) and district 5 (outer). However, some areas with very good Western medical services such as district 1 (inner) had very large number of lawsuits.

d) Most of the soup-kitchens were distributed in districts with poorer Western medical services, e.g. district 4 (inner). There were some soup-kitchens distributed in areas with the best Western medical services such as district 1 (inner) and district 2 (inner).

7.6 Significance Testing of Spatial Variations

When the GWR technique is employed to analyze a given data set, it is necessary to test whether the GWR model describes the data set significantly and whether each set of its parameters vary significantly across the study area. A GWR model normally fits a given data set better than a global model. However, from the practice point of view, the simpler a model, the easier it can be applied and interpreted. If a GWR model does not perform significantly better than a global model, we would rather choose the global model in practice. Furthermore, to specify which set of the parameters vary significantly over the study region would help to better understand the data and research inquiries.

There are two approaches which allow significance testing for the variability of individual coefficients: Monte Carlo approach (Fotheringham et al. 1997a, b; Brunsdon et al. 1999) and Leung et al. approach (2000). Both approaches have been proven as computationally intensive but they are the relatively mature techniques available for the time being. We adopt Monte Carlo simulation to perform tests on the validity of the GWR model in the Beijing medical service analysis as it is easier to implement. In this technique, under the null hypothesis that the global linear regression model holds, any permutation of the observations $(y_i; x_{i1}, x_{i2}, ..., x_{ip})(i = 1,2,...,n)$ among the geographical sampling points is equally likely to occur. The observed values of the statistics proposed can then be compared with these randomization distributions and the significance tests can be performed accordingly.

The testing results are shown in table 7.3 and 7.4.

Table 7.3 Test for spatial variability of parameters for TCM providers

Parameter	P-value
Intercept	0.24000
Hospital	0.62000

Temple	0.00000
Industry-commerce	0.34000
Tap	0.26000
Lawyer	0.97000

Table 7.4 Test for spatial variability of parameters for Western hospitals

Parameter	**P-value**
Intercept	0.68000
Temple	0.87000
Church	0.48000
Tap	0.98000
Lawyer	0.87000

The results of a Monte Carlo test on the local estimates for TCM providers indicates that there is significant spatial variation in the local parameter estimates for the variable temple. The spatial variation in the remaining variables is not significant and in each case there is a reasonably high probability that the variation occurred by chance. For Western hospitals, the results of a Monte Carlo test on the local estimates indicate that none of the variables are significant.

This is useful information because now in terms of mapping the local estimates, we can concentrate on the temple variable, for which the local estimates exhibit significant spatial non-stationarity.

7.7 Summary

We have applied GWR to analyze the spatial variations of the relationships between medical services and factors like population, temple, church, industry-commerce, tap, lawyer and school in the 1930s. The major findings are listed as below:

For TCM services,

a. The western areas of the North City had a higher basic level of TCM services than the other areas if other variables are considered the same.

b. Western hospitals had a negative statistical impact on the presence of TCM providers in most areas of Beijing city.

c. The temple variable played a more important role affecting TCM services in the South City than in the North City.

d. Industry-commerce had a greater effect on the presence of TCM providers in the North City than in the South City.

e. Taps had a positive statistical impact on the presence of TCM providers over Beijing city.

f. Lawyers had a positive statistical impact on the presence of TCM providers in most areas of Beijing city and had the greatest effect in the southwest.

g. However, only the temple variable displayed statistically significant spatial non-stationarity.

For Western medical services,

a. The North city had a higher basic level of Western medical services than the South City if other variables are considered the same.

b. Temples had a negative statistical impact on the presence of Western hospitals over Beijing city.

c. Churches had a greater effect on the presence of Western hospitals in the South City than in the North City.

d. Taps had a positive statistical impact on the presence of Western hospitals over Beijing city.

e. Lawyers had a greater statistical impact on the presence of Western hospitals in the Western areas of the North City than in the other areas.

f. However, these variables did not pass the statistical test of spatial variability.

Concerning the relationships of medical services with poverty, toilet, lawsuit and soup-kitchen patterns, we have found out:

a. Districts with better medical services had relatively less poverty.

b. There were more toilets distributed in districts with poorer medical services.

c. Districts with better medical services normally had fewer lawsuits. However, district 1 (inner) was an exception. This district had very good Western medical services but very large number of lawsuits.

d. Most of the soup-kitchens were distributed in districts with poorer medical services. The soup-kitchens seemed to have a closer relationship with Western hospitals than TCM providers.

CHAPTER 8: CONCLUSIONS

8.1 Summary of the Research

We have applied an historical GIS approach, which focuses on the spatial dimension as well as quantitative analysis, to explore aspects of the medical services in Beijing from 1912 to 1937. We have provided a framework for successful integrated data management by establishing the Republican Beijing historical information management as an organizational priority. Based on this framework, we have established a system that integrates the functions of data storage, selective retrieval, analysis, display and archiving. First, an historical GIS database has been produced in which public health, urban morphology, education, religion, market and legal cultural observations can be accessed by any investigator throughout the Republican Beijing medical community. Second, four kinds of spatial analytical methods, including buffer analysis, two-step floating catchment area method, spatial auto-correlation and GWR have been integrated and used to explore the spatial patterns of medical services and its correlation with a wide range of social, economical, religious, educational and legal factors.

Republican Beijing historical information management includes three parts: data collection, database management and data analysis. The data are collected and prepared according to six cultural spheres: public health cultures, urban morphology, market cultures, education cultures, legal cultures and religious cultures. The geo-database data model is used to represent and manage these data. Buffer analysis, two-step floating catchment area method, spatial auto-correlation and GWR are selected and integrated to investigate some aspects of the medical services in Beijing.

The Republican Beijing historical GIS database is built accordingly. Four historical maps of 1913, 1916, 1937 and 1940 are used to create the base map as the foundation of spatial data. The rubber sheeting method is used to geo-reference historical maps. Spatial data are acquired through digitizing while attribute data are derived from historical materials which are stored in access database. A coding system is developed to link the spatial data with attribute data. The metadata of the database are documented according to the standards of Dublin Core, ISO19115 Geographic Information-metadata and Chinese Geographic Information – Metadata standard.

There are two problems encountered when building this historical GIS database. One is that the digital representation is of lower accuracy to the sources due to the limitation of the scale of the base map. There is a great deal of Beijing medical historical information containing street number information which is not identified on the base map as the basic geographic unit of the base map is the hutong. We have provided a solution to work out the sequence of street numbers. This solution has created a standard for the sequence order of street numbers, which improves the accuracy of the database. The other is the Modifiable Areal Unit Problem (MAUP). There are only 11 or 20 police districts for Beijing city, which limits the application of spatial analysis. We have created 80 new districts by grouping the blocks on the base map together. An approach has been developed to further break down the population pattern from 20 police districts to 80 districts as well. This process allows us to conduct spatial analysis based on smaller areal unites, making it viable to reveal the details of variations in the spatial patterns of medical services in Beijing.

Based on the Republican Beijing historical GIS database, Moran's I statistics and hotspot analysis are used to analyze the global and local spatial autocorrelation of TCM and Western medical services in the 1910s, 1920s and 1930s. We have demonstrated the characteristics of distributions of TCM providers and Western hospitals and how those patterns changed over time. The spatial distribution of TCM providers is clustered over the whole period but the significance decreases gradually. Western hospitals appear to be randomly distributed in 1914 but become clustered in 1929 and 1935. The spatial patterns of medical services can be described by using an approximate north-south split. The South City had better TCM services while North city had better Western medical services in the 1910s and 1920s. The north-south pattern for TCM changed in the 1930s but was enhanced for Western medicine in 1935.

The two-step FCA method and buffer analysis are used to measure the spatial accessibility to TCM and Western medical services and their relationships with the urban traffic in the 1930s. We have demonstrated the characteristics of distributions of TCM and Western medical resources and how the urban traffic affected these patterns. The central areas had better spatial access to TCM services than the other areas of Beijing. While the North City had better spatial access to Western medical services than the South City. The urban traffic had a great impact on the presence of Western hospitals. The better the road, the more Western hospitals adjacent to it. However, there is no strong relationship between the urban traffic and TCM.

GWR is used to analyze the spatial non-stationarity of the relationships between medical services and factors like population, temple, church, industry-commerce, tap, lawyer and school in the 1930s. We have demonstrated the characteristics of spatial variation and the relationships between TCM, Western medical services and their associated factors. For TCM, The western areas of the North City have the highest basic level of TCM services. Western hospitals had negative statistical impact on TCM providers in most areas of Beijing city. Temples played a more important role affecting TCM services in the South City than in the North City. While industry-commerce had a greater effect on TCM providers in the North City than in the South City. Taps had a positive statistical impact on the presence of TCM providers over Beijing city. Lawyers had a positive impact on TCM providers in most areas of Beijing city and had the greatest effect in the southwest. Only the temple variable displays statistically significant spatial non-stationarity. For Western medicine, the North city had a higher basic level of Western medical services than the South City. Temples had a negative statistical impact on the presence of Western hospitals over Beijing city. Churches had a greater effect on the presence of Western hospitals in the South City than in the North City. Taps had a positive statistical impact on the presence of Western hospitals over

Beijing city. Lawyers had the greatest impact on Western hospitals in the Western areas of the North City. However, these variables did not pass the statistical test of spatial variability. In addition, spatial patterns of TCM providers, Western hospitals, poverty, toilet, lawsuit and soup-kitchen based on the 11 police districts show districts with better medical services had less poverty and fewer lawsuits while districts with poor medical services had more toilets and soup-kitchens.

8.2 Contributions

This present research promotes an explicitly spatial view of TCM and Western medical services in Republican Beijing that has conceptual and methodological implications for Beijing medical history studies. The contributions are two-fold:

For Chinese medical historical studies, the present research provides a new perspective and methodology, which is focused on the spatial dimension as well as quantitative analysis, which has been ignored in the previous work.

First, the diversity and richness of the information is systematically incorporated into a conceptual framework of analysis through the application of GIS technique. It is the first attempt to collect and process such information about Beijing in a medical historical context.

Second, a better understanding of the spatial patterns of TCM and Western medical services and their correlations with a wide range of variables is acquired through the application of spatial analysis and spatial statistics based on GIS.

For GIS, the present research provides a framework that successfully manages integrated data for medical service studies in Republican Beijing. Historical data coming out of the historical enquiries are collected, processed, organized, managed, analyzed and displayed in a GIS environment.

First, the Beijing medical historical GIS database is built. The approach of identifying the street number on hutongs improves the accuracy of the database and the approach of zoning 80 districts solves the Modifiable Areal Unit Problem. In fact, these are very common problems in historical GIS research which are concerned with "accuracy" and "scale" as historical data are frequently inaccurate and sparsely sampled. These two approaches seek to address such problems.

Second, four kinds of spatial analytical method, buffer analysis, two-SFCA method, spatial autocorrelation and GWR are integrated and used to analyze the TCM and Western medical services. It is the first attempt at applying spatial analysis and spatial statistics to Beijing medical historical studies. The spatial patterns of TCM and Western medical services and their interplay with various variables are revealed.

8.3 Limitations and future directions

The first direction is concerned with the data and variables used for the analysis. On accessibility to medical facilities, a simple overlay of the points with the districts to identify the number of facilities within each district, and thus the density of TCM providers and Western hospitals makes more sense. On buffer analysis, we can simply compute the ratio of western vs. TCM facilities within distances along different types of road. We may find some interesting patterns: for example, higher ratios of western facilities along major roads than minor roads. On spatial autocorrelation, we can compute a density of medical facilities (e.g. medical facilities /population) for each areal unit, then we have two variables for each unit to evaluate the spatial relationship between locations of western hospitals and TCM providers. On spatial non-stationarity, there can be further differentiation of the data like separate patterns of industrial organizations and commercial organizations, which may create new patterns of interest. For both spatial autocorrelation and GWR, it would be best to use continuous data rather than count data because count data is usually treated in a different way. We can use the density of TCM/ Western medical facilities instead of counts.

The second direction is to improve the spatial analytical methods used in the present research. The two-SFCA method uses a simple population (demand) to practitioner (supply) ratio within a region to measure the spatial distributions of medical resources. It is effective for Western medicine but inadequate for TCM because TCM services were widely supplied in not only TCM clinics but also TCM drugstores, temples, temple markets and guilds. Therefore, a better ratio needs to be provided to reflect the distribution of TCM resources more objectively. For hotspot analysis, the different threshold distances may have some implications in the historical context and the choice of a certain threshold distance can be justified by developing other approaches. For GWR, a poisson GWR may be more appropriate as the dependent variables are counts. This can be further developed and the results can be compared with the Gaussian GWR used in the present research, which may provide new findings of GWR application to historical data.

APPENDIX A

Metadata for Historical GIS Dataset of Urban cultures in Republican Beijing

Citation_Information:

Dataset_Full_Title_in_Chinese: 民國時期北京都市文化歷史地理資訊資料庫

Dtatset_Shorten_Title_in_Chinese: 北京歷史地理資訊資料庫

Dataset_Full_Title_in_English: Historical GIS Dataset of Urban Cultures in Republican Beijing

Dtatset_Shorten_Title_in_English: Beijing historical GIS database

Version: 1.0

Serial name: Beijing Historical Geographic Information System

Publication_Information:

Publication_Date:

Project_Information:

Project_Name: Beijing in transition: A Historical GIS Study of Urban cultures, 1912-1937.

Project_Category: Supported by Research Grant Council Research (Project Number: 450407)

Responsible_Party_Information:

Responsible_Party_Name: Department of History, the Chinese University of Hong Kong

Responsible_Person_Name: Billy.K.L.So

Role_of_Responsible_Party: Oraganization and Management

Country: China

Administrative_Division: Hong Kong Special Administrative Region

City: Hong Kong

Address: 1/F, Fung King Hey Building, The Chinese University of Hong Kong, Shatin, N.T..

Postal_Code:

Website: http://www.history.cuhk.edu.hk/new/

E-Mail_Address:

Telephone_Number: (852) 2609 7117

Fax_number: (852) 2603 5685

Range_of_Datasets:

Geographic_coordinates:

West_Boundary_Coordinate: 116.350125°E

East_Boundary_Coordinate: 116.427675°E

North_Boundary_Coordinate: 39.951379°N

Sorth_Boundary_Coordinate: 39.865149°N

Geographic_Area_Name: Beijing City (not including suburban areas)

Temporal_Extent:

Temporal_Extent_Category: 2

Time 1: 19120101

Time 2: 19371231

Scale: 1:5000

Dataset_Language: Simplified Chinese

Dataset_Content_Information:

Abstract:

This is a historical GIS study of the Beijing city from the fall the Manchu empire to the fall of the city into the hands of the Japanese army, with emphasis on its urban cultural diversity and transformation.

There are three main objectives:

a) to develop a GIS dataset of historical information on six selected urban cultural spheres, constructed on large-scale digital base-map;

b) to document the spatial patterns and changes in each of these urban cultural spheres;

c) to explore through vigorous GIS analysis the theoretical implications of the integrative patterns generated from the interplays of the six spheres.

The six cultural spheres constitute the main contents of the database. They are:

a) Urban morphology - city planning and structure, major government buildings, major landmarks, urban population patterns, and transportation patterns.

b) Market cultures - firms and shops of major businesses, banking and pawnshops, manufacturing enterprises, guilds, temple markets, urban

taxation, land price, wage patterns, poverty patterns.

c) Education cultures - schools, universities, professional education organizations, traditional education providers, literacy providers.

d) Medical cultures - traditional health care providers, modern hospitals and clinics, public health services, Chinese and western drugstores, patterns of common and infectious diseases, hygienic facilities.

e) Legal cultures - police forces, military police, crime rates, medication, court systems, civil and criminal litigations, lawyers and law firms.

f) Religious cultures - temples, churches, properties, membership, leadership, welfare services.

Most of the information is available in archives and libraries in Beijing. The approach is interdisciplinary, involving the fields of history, urban study, historical geography, GIS study, economics, law, public health, education, and religion.

Purpose: used for Republican Beijing urban culture studies.

Completeness: Complete

Topic_Category: Historical geographic information

Key_Words: Republican Beijing Urban culture Historical GIS database

Constraint_Information:

Access_constraints: read only

Use_Constraints: free and public

Lineage:

Data_Quality: Feature points can be plotted according to street numbers.

Spatial_Representation_Type: Vector

Data_Items:

Spatial_Reference_System: latitude and longitude

Publication_Information:

Publication_Unit_Name: Insititute of Space and Earth Information Science, The Chinese University of Hong Kong

Publication_Format: ARC/INFO

Publication_Media: CD-R

Data_Size: 106 MB (uncompressed)

Online_Publication_Address:

Online_Browing_Address:

http://www.iseis.cuhk.edu.hk/history/beijing/

Price:

Metadata_Reference_Information:

Metadata_Level: First

Metadata_Responsible_Party: Insititute of Space and Earth Information Science, The Chinese University of Hong Kong

Metadata_Responsible_Person: Peiyao zhang

Adninistrative_Division: Hong Kong Special administrative Region

City: Hong Kong

Address: Fok Ying Tung Remote Sensing Science Building,

The Chinese University of Hong Kong, Shatin

Postal_Code:

Telephone_Number: (852) 26096538

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