Evaluation of Accessibility to Primary Schools
——The case of Yuhua, Changsha, China

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by

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ABSTRACT

There are a lot of examples of some common resource allocation dilemmas for public facility faced by planners and policymakers everywhere. Policymakers need have an insight in how well current facilities perform, and then decide how to improve the performance to ensure the service is provided at the most effective location where the demand is the most.

Currently, the conventional planning method is used popularly, but it does not incorporate the concept of accessibility and cannot give accurate demand-supply information. In this point, a more detailed method is a useful tool to analyze accessibility.

Yuhua district in Changsha, China is selected as the study area in this research. This thesis evaluates the accessibility to public primary school in the current situation and in the plan of the year 2020, in terms of supply and demand from two perspectives: spatial distribution and capacity, integrated accessibility theory and GIS. It also proposes patterns to improve the accessibility to public school by selecting acceptable service centre locations. Coverage percentage is used to guide the quantifying of performance and the comparisons of the demand and supply is used as the supplement of performance. To investigate the usefulness of the integration of accessibility theory and GIS, the comparisons between the current situation, the plan and the proposed pattern are carried out in this research. These results may give reason for a selection among different plan alternatives and location new service centres.

The results indicate the accessibility analysis can reflect the relationship between the supply and demand in more detailed than conventional method. The results also prove the developed method is an effective way to evaluate accessibility and to propose acceptable centre location and to suggest proper capacity of public facility. Integrated with GIS, it is easy to delineate the serviced and unserviced area and to interpret the results.
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1. Introduction

1.1. Background

Education plays an important role in our society. United Nations Educational, Scientific, and Cultural Organization indicate that the development of education is in advanced to the development of economy all over the world. Word bank points out that the GDP of a country will increase 3% every one more year education to a labourer. Furthermore, education is an effective way to eliminate poverty and to prosper the economy and society. Hence it has been brought to the agenda of the government. In any city, the accessibility of services affects the distribution of wealth among citizens. As Lineberry (1997) states, urban policies is essentially a policies of spatial allocation of advantages and disadvantages. Toulmin (1998) specifies the ideal goal of city government as providing services to maintain the viability of each neighbourhood. In urban environment, school planning is a type of facilities planning and the distribution of schools means the availability and accessibility for people’s schooling, furthermore, the practical importance of school location in urban area is based on the needs of the residents. The planning of the primary school is of vital importance for urban development. In order to satisfy the demand for the primary school and to ameliorate the quality of the service, the government attaches importance to the planning of primary schools. In 2003, the Changsha municipal government decided to do the primary and middle school plan of the year 2020 which concerns the location and capacity of the school in the metropolitan area of the city, in order to solve the problems in reality.

The primary school is the base of the education. Taking the available data into account, in this research, only the primary school is concerned.

In Changsha, the selection of primary schools is based on the principle of the nearest distance from settlement to school in order to ensure an easy and safe travel. The ideal location of primary school should incorporate the principle that minimizes the sum of the overall home-school distances. Thus, it takes children shorter distance to primary school. In practice, the education authority ordains the each primary school jurisdiction according to the students’ “Hu Kou” which is limited by the students address. The location and size of the primary school is planned by the local planning and design institute. The demand for the primary school educational facilities at any given time is the number of school-age children from 6-12 years old (primary school-age in China). The primary education is compulsory to each child, which means normally, the age group of 6-12 years must attend the required primary school and no one can be excluded. But part of the minority normally attends the minority school and some high income group select private school. The primary school enrolments ratio in 2002 is 99.9% (educational statistics gazette in 2002).

But currently, in most practical planning work in China, the analytical method to this problem in urban planning is (Peng Mingjun 2003): to take the schools as points (supplies or resources), and the
students (demands) around them as areas, the demands to the resources are calculated according to experience or local standards, and the service area is just calculated by drawing a circle around the schools according to a specified radius, then summing the total students within the area and comparing this value to the school capacity to calculate whether the school meet the students demand. This method is similar with the school plan studied by Chapin (1965) and the work is finished in AutoCad, not in GIS.

1.2. Problem Statement

In China, primary schools are mostly public and mainly provided by local government. For example, in Changsha, China, there are 308 public primary schools and 5 private primary schools. As far as public primary schools are concerned, many problems arise in the schools of this city:

- **Unequilibrium distribution of schools**
  The distribution of schools in Changsha is obvious uneven. In terms of density, it shows a high concentrated pattern with a peak around the central area. The old area has the largest share of schools while the developing area is short of them. According to the local standard, a new resident district larger than 4000 peoples should have a primary school (Changsha city governmental document No.15, 2000). Therefore some developer motivated by less investment cost built residential area within this scale and resulted in two or three adjacent residential quarters without a school (Xinkaipu area of Changsha). The people living near to city center have a high level of access to schools and people at living on the periphery, a low level.

- **Too limited space for schools**
  The primary schools have been left without adequate space concentrated in a few districts where land-value is expensive. Some schools are short of playground and green space even if enough classroom. There are 480 students in Chao Zhongjie primary school and the area of the school is 1475 square meters, which means 3.07 square meters per student and fall behind the province standard (Changsha educational standard for primary and middle school, 2001) of 15 square meters.

- **Overloaded capacity of some schools**
  According to the national standard, the average number of a primary school is 45 students in a class, while most high quality schools in city center has reached 64 students in a class.

- **A few schools lack of students**
  A school only has 3 classes and 69 students totally in Yuelu district. The facility is poor, equipped only a main building, lake of playground, library, etc.

The relationship between the problems is described as Figure 1-1. These phenomena are common not only in Changsha but also in China. To school-age children, long distance travel to cluster in a school is inconvenient. And the country standard of China ordains the service radius of the primary school is 500 meters (The standard of primary and middle schools’ design GBJ 99-86, 1987). If the actuality of every school is integrated, can a uniform service radius, 500 meters, solve the problems between the demand and the supply?
There are several existing primary schools but the spaces are too small to accommodate the students and it cannot bear the task to service the demand. It is necessary to improve the condition of the school, or the school should be united with a nearby one or should be closed. If another school has enough capacity that it can offer schooling to 500 meters area, it should be reserved. So, it is indispensable to calculate characteristic of the school. Analysing these problems can simply be stated as matching supply and demand relationships over space. There is a varied demand for different neighbourhoods and this demand can be satisfied by different schools.

All the times, there are many voices for increasing the finance of government on education, so many changing pattern of education are arisen, comprising informationized education and far-distance education. But to primary education, these cannot solve the problems ultimately. These trends make the planning more complex and what should to be considered is the first question to face for all developers in schools planning.

Measurement of such diverse states is a difficult and complex process that requires dedicated researchers and creative research across many fields. It is more complicated to relocate the current schools than to locate a new middle school because they are affected by more factors including natural conditions, the existing distribution, and so on. Therefore, the planners must combine all these factors to make the plan in order to satisfy the demand, which is the conceptual aspect of set of processes aimed to deliver desired services in a certain area. Indeed, the convenience methods for schools should be carefully re-examined and refined from a single plan toward a more comprehensive plan.

1.3. Objectives

1.3.1. Main Objective

The main objective of the research is:

To develop a methodology to evaluate the accessibility of the current primary schools and the plan for the primary school in 2020.
1.3.2. **Sub-objective**

1) To develop a GIS based approach capable of analyzing the accessibility of existing primary schools
2) To analyze the accessibility of primary school plan of the year 2020.
3) To give suggestions to promote the accessibility of primary schools.

1.4. **Research Questions:**

The research questions related to the above objectives are:

**Sub-objective 1:**
- What kind of data is needed to do the research?
- How to process the data?
- How to demarcate the study area?
- What software can be used to do the analysis?
- How to measure the accessibility of the current distribution?
- How to grade the performance of the current in accessibility?
- What are the existing problems on accessibility in the current distribution of schools in the study area?

**Sub-objective 2:**
- What is the difference between the accessibility analysis of the current and of the plan?
- Has the plan improved the accessibility?

**Sub-objective 3:**
- How to improve the accessibility?
- How to check the proposed suggestions to improve the accessibility?
- What is the conclusion?

1.5. **Research Framework**

The above questions are explored with the aid of a diagram (Figure 1-2), which portrays the research framework of this study, so the case is carried out by using a measure of accessibility in the evaluation of the existing distribution, the proposed pattern for the existing distribution, the plan and the proposed pattern for plan. Comparisons are performed between the performances of four patterns to compare the efficiency of one program with another.
Define Study Area

Define Problem

Formulate Objective

Literature Review

Select the Accessibility Measure

Collect Data

Identify the Data Required

Process Data

Analysis Phase

Analysis on The Existing Distribution (1999)

Identify Problems of The Plan

Propose solutions

Analysis on The Plan (2020)

Grade the Accessibility Performance

Grade the Accessibility Performance

Grade the Accessibility Performance

Comparison

Comparison

Conclusions

Figure 1-2 Research flowchart
1.6. Structure of the Thesis

The thesis is composed of seven chapters.

The first chapter, the topical context of this study is presented and some general information is given about conventional planning in China, which consists of the research background, problem statement, research objectives and questions. The research context of this study is clarified.

In the second chapter, background practice on public facility planning in China and relative theories on accessibility will be presented. Accessibility measure, its application and development on public facility planning will be drawn main attention. Contour measure as an approach to measure accessibility is also described in this section.

Chapter three describes the introduction of the study area. The population, land use, and data collection will be mentioned. Scope of the study is also presented in this chapter.

Chapter four explains the process of data preparation. It also deals with disaggregating population, incorporation of unsafe aspects on the route to school for children and calculation of capacity of each school.

Subsequently, Chapter five, the methodology for analyzing accessibility is discussed, including the analysis on the existing primary schools, proposed pattern for the existing situation, the plan and the proposed pattern for plan, from the perspectives of spatial distribution and capacity.

Chapter six concludes the analysis of the results. The performance of each pattern will be scored based on coverage percentage and comparison of the demand from residents and the supply of school.

Finally, Chapter seven provides the conclusion of the research from the analysis done in the above.
2. Overview on Public Facility Planning and Accessibility Analysis

2.1. Introduction

The public facility is defined as the facility to which people must travel to receive the service, or from which a service is provided to the whole community of interest in administration, economy, education, health, scientific research and physical training (China Standard GB/T. 50280-98 1998). They provide important goods and services which contribute to and enhance the quality of life (Massam 1993). They include schools, libraries, stadiums, hospital, clinics and other public facility. Public facilities are important because they both provide desirable services to and impose undesirable impacts on those who use the city, and from the market perspective, land to be developable must have access to a network of facilities. The primary school is an important part of public facility and primary school planning is a type of facility planning (Massam 1980). It is generally felt that the closer the facilities (desirable facilities) are to the users, the better the service provided.

What keeps residents in metropolitan areas is accessibility, the potential for interaction, both social and economic, the possibility of getting from home to a multitude of destinations offering a spectrum of opportunities for work and play (Handy 1997). The term “accessibility” should be in the language of planners and should be utilized to generalize statements of planning goals, so the need for and the effectiveness of alternative scenarios can be evaluated.

The introductory section gives an overview of background information on public facility planning in China and accessibility theories.

2.2. Conventional Planning in China

2.2.1. The system of plans

In China, urban land is in the hand of the state. The enactment of the 1989 City Planning Act is a major milestone that tries to re-establish and formalize the urban planning system to meet the challenges from economic reforms in 1978. The City Planning Act states that urban planning consists of two tiers, i.e. the master plan and the detailed plan. At the top tier is the master plan that outlines the general land use pattern of the city. According to the explanatory note of the Act, the master plan usually has a planning horizon of 20 years and should consider the long-term development strategies. The center task of the master plan is organization of urban space. The short-term plan is one element of the master plan, which should decide the layout of urban development in the near future and arrange the coming developments. Below the master plan is the detailed plan for the area that faces immediate development or is specified in the master plan. The urban planning system is evolving from a two-tier system to a multi-layer system and it should be noted that a great geographical diversity exists, i.e. the actual practice of urban planning is different form city to city. This research treated the universal planning practice.
2.2.2. The amendment of plans

The implementation of the master plan relied on the understanding of the plan by government officials and the ‘translation’ of it into the action of resource allocation. The master plan does not specify which government department should invest what, so it is not closer to the real decision making process than economic planning. The plan-making process carried out by the planners is separated from the politics in the real decision making process in land development. It is not surprising that very often the master plan cannot be implemented. The plan is not invariable because of a quick change in our society. Article 22 of the Act stipulates the right of planning amendment. The city government is entitled to make partial adjustment to the master plan of the city according to the needs of the city’s economic and social development and the amended master plan should be submitted to the standing committee of the People’s Congress of the corresponding level. Major adjustments which involve the designated function of the city, the scope, economic orientation and structure and general spatial structure of the city should be examined and approved by the People’s Congress of corresponding level to its standing committee (Anthony & Fulong Wu 1999). Normally, the term of the amendment is five years. Therefore, in this study, the objective is to develop a methodology, which can deal with a diversity situation using different data. The methods that are suitable for analysis of the plan in 2020 might also fit the plan in 2010.

2.2.3. Neighbourhood design

Good public facility planning has much relationship with an effective land use planning, especially, neighbourhood design. A reasonable concentrative neighbourhood design results to more people share a common facility, so locating facility and improving the quality is more convenient than a scattered residential area.

There are three kinds of neighbourhoods, residential district, residential quarter and housing cluster in Chinese cities in terms of the population of the neighbourhood, which ranges from 1000 to 7000. From Figure 2-1, it can be seen that a residential district (1) comprises several residential quarters (2), a residential quarter is made of several housing clusters (3) (Dehua L., 2001)

2.2.4. The plan making process for primary schools

The conventional method in primary school planning involves first a determination of the number of facilities needed, which is estimated based on the percentage of school-age population to the total population forecasted. According to the population growth rate in recent years the forecast is performed. Finally the total space needed for each facility is calculated by multiplying the total number of pupils by the space per pupil requires. Space requirements are assigned to the appropriate planning districts in which each such facility is located. As in the space analyses stage, a frequently applied planning technique is the drawing of a circle around public facilities, with a fixed radius-reflecting...
norm of a policy standard. Observing the result theoretical service area, a distinction could be made between areas, which are properly served (serviced area), and those are not (unserviced area).

Public facilities planning normally applied planning standards. In dealing with the standard for the location of schools, the easy walking distance from residence to school is defined in distance standard, usually in terms of meters of travel. In China, access standard is 500 meters constituted by the Ministry of Construction, so, a map of school sites with 500-meter circles described around each site provides only the very crudest measure of facility adequacy. Figure 2-2 shows this process like buff tool in GIS. School capacities are measured by the size, generally 15 square meters per pupil in city center while 18 square meters in the periphery, with a maximum of 45 pupils per classroom (Changsha city educational standard for middle & primary schools, 2001). So, these requirements will vary with different residential densities.

Since economic reforms in 1978, there have been some spontaneous changes in the plan making process changes in the plan making process by the Chinese urban planners in order to achieve better planning effectiveness. But there are still many deficiencies of the urban planning practice in dealing with the rapidly changing socio-economic environment. With the popularity of the computer technique, many drawing blueprint of planning are finished in AutoCad software, which advance our work efficiency, but the concepts of GIS and Accessibility have not penetrated into the analysis process before drawings. Planning on the base of country standards considers the concept of accessibility subconsciously to assure the students can visit the nearest school.

![Buffer Analysis of Primary School](image)

Figure 2-2 Buffer analysis of primary school

(Radius: 500 meters)

The concept of accessibility has been applied gradually (Zeng Song 2001, Yu Kongjian 1999, Zhang & Li 1997, Song & Niu 2000) in planning but not expanded widely as an analytical tool in China.
From a broader examination of current accessibility analysis, it can be seen that abundant examples are demonstrated in the Netherlands. K.T. Geurs and J.R. Ritsema Van Eck (2001) review accessibility measures for their ability to evaluate the accessibility impacts of national land-use and transport scenarios, and related social and economic impacts. Some others treat with service centres location, hospitals relocation, schools closure, individual shops sitting (T. de Jong 1991) and parking problems (Ritsema van Eck 1990). In the United Kingdom, the accessibility measures are used in planning primary service (D. Martin 1992) and in analysing accessibility of primary care to urban patients (Knox 1979). The rural accessibility problem was undertaken by Moseley in 1970s. In Irbid, Jordan, the analysis of public services and transportation is discussed (Khaled Al-Sahili 1992). In the USA, State Departments of Transportation and Metropolitan Planning Organizations are increasingly turning to accessibility measures in their planning processes. Accessibility measures were computed to analyse accessibility to public playgrounds (E. Talen 1998), to describe non-work choices at the local scale in the case of San Francisco Bay Area and to describe work mode and destination choices at the regional scale in King Country, Washington (Handy 1997), etc. More and more countries are beginning to determine how best to interpret accessibility and incorporate it into their planning processes.

Moseley (1979) defines three basic components of rural accessibility: people, activities and links. Accessibility affected by the spatial distribution of the destination and the origin, as a bridge to link them, intends to describe the ease of reaching each destination and the quality, character of the activities found there. Supply refers to the quantity of resource a facility, referred to as a center, has available for utilization through the network. Demand quantifies the utilization of the resource as portions of the network are assigned to the center. So, accessibility should be a good tool to depict the activities between the demand (origin) and the supply (destination).

2.3. Concept of Accessibility

The above is conventional method of public facility planning. Facility or service siting is still a popular topic in geographic research. In this context, accessibility analysis is applied widely in the public facility planning to examine patterns of accessibility to certain services and the geographic relationship between provisions and needs.

2.3.1. Definition of Accessibility

It believed that accessibility is a concept that has taken on a variety of meaning, including “the amount of effort for a person to reach a destination” or “the number of activities which can be reached from a certain location” (K.T. Geurs & J.R. Ritsema Van Eck 2001). They define accessibility as the extent to which the land-use transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (a combination of) transport mode(s), in other words, accessibility concerns both on the pattern of activities and on the links between activities.

The concept of accessibility is used in many contexts and in different ways, for example, as a goal in transportation policy, as a means in rural development policy, as an indicator of rural deprivation, and as a variable in location analysis (Moseley 1979). We define a location to be accessible if the effort it takes to get there is acceptable to the target group; so the concept of accessibility incorporates not only the transport link between origin and destination and the ability for travelling by the target group,
but also characteristics of the destination and the objective of the trip (T. de Jong & J.R. Ritsema van Eck 1996).

2.3.2. Components of Accessibility

Moseley (1979) argues that the basic notion of accessibility embraces three components:
- People, the residents of rural areas;
- The activities or services which they require;
- The transport or communications link between the two.

Figure 2-3 gives a description of the components of accessibility.

![Figure 2-3 Components of accessibility](image)

Source: Moseley (1979)

Both the size and the composition of the population affect the accessibility because they determine the scale of the demand or the need for public services; the links reflect the travel time costs and effort to travel between an origin and destination location; the activities reflect the spatial distribution of activities at destinations and the demand for those activities. This argument is also a power evidence to demonstrate accessibility can illustrate the spatial relationship between the demand for and the availability of public facilities.

2.4. Accessibility Analysis in Public Facility Planning

2.4.1. Importance of Accessibility in Public Facility Planning

The urban area is seen as a resource or opportunity pool in which resources are unevenly distributed and to which people are likely to have different degree of access. Such resources represent “income” to those who benefit from them. Different degrees of access to these spatial opportunities will thus affect the real income of different groups (Breheny 1978). Furthermore, accessibility can be applied between two places to show the relationship between the location of the services (supply) and the location of the settlements where the people that would use these services (demand) live.

School resources including quantity and capacity are inevitable limited. In planning and management of primary school delivery, therefore, account needs to be taken of spatial variations in school needs and accessibility in order to ensure that services are provided at the most effective locations. Broadly
speaking, the general aim of a location pattern, for a given set of public facilities, is twofold. First, be as near as possible to demand, in order to reduce transportation costs. Secondly, keep the cost of establishing the facilities as low as possible, by reducing the number of facilities to be established. Accessibility is an important concept in this respect (Leonardi 1981).

Accessibility analysis can be applied to various stages of the facility sitting procedure. First, existing facilities can be evaluated in order to estimate their respective catchment area which may indicate that some facilities should be relocated or closed. Second, all locations in the area can be evaluated for a single new facility to be added to the set of existing facilities; in this way, an accessibility surface can be constructed that can help the decision maker in choosing a suitable site. Third, the decision maker can make one or more proposals for a new location pattern, either based on the existing locations with maybe some relocations and a number of new facilities, or based on completely new locations (T.de Jong 1991). These proposals should then be evaluated by accessibility analysis in order to assess the relative quality of the different proposals in more detail and identify the one that best serves the objectiveness of the decision maker.

2.4.2. GIS in Accessibility-based Public Facility Planning

Both in the conventional planning and in the modern planning, spatial information is needed. GIS systems specialize in exploring and interacting with spatial information. More specifically, a GIS is a computerized system capable of collecting, storing, manipulating, retrieving and displaying spatial information which is the data identified according to location. GIS provides the decision maker with information for the extraction of data regarding the location and distribution of service centers. Furthermore, it provides visualization tools. Visualization of a problem’s context and structure and its alternative solutions is one of the most powerful components of decision support. Maps are not only a familiar and easy-to-interpret format, but provide an ideal vehicle for the organization of complex spatial information when combined with other symbolic and graphical forms of representations. By utilizing the spatial analysis of GIS, mismatches of the supply and demand in the pattern of service provision can be identified. The spatial analysis approach can help in presenting the degree of match between service demand and supply more distinctly on maps.

The last decade has seen an upsurge in the use of GIS-based accessibility analysis for business planning, where expected marked area size is a key factor in the location decision. In the context of GIS-based location analysis, there is a need for simple, effective, indicators of market accessibility that can be easily visualised. Analysis based on the concept of accessibility is therefore ideally suited to be integrated with GIS (J.R. Ritsema van Eck 1999). In this article, this aspect of accessibility will be focused to analyse demand as the most important geographical factor in the primary school planning, ignoring other important factors that influence any real-world location decision, varying from legal and economical to social and psychological. In our context, the aim is to maximize access of the pupils to the primary school; therefore, we use the concept of accessibility mainly in two aspects: coverage percentage and capacity based on its components: people (demands), transport and activities (destinations).

A number of spatial analysis techniques are available to the decision maker searching for a location with good accessibility for expected customers. Two important groups are impact analysis or “what if?” models and optimisation techniques or “what should be?” models (Birkin 1996). Examples of
optimisation models are location-allocation models. They allow one to find the best location for a new facility (or the best set of locations for a number of new facilities) from the viewpoint of accessibility to customers. In many cases it turns out to be difficult, if not impossible, to integrate other considerations than accessibility with the results of this type of technique; for instance, there may not be any suitable building available near the computed optimum location (J.R. Ritsema van Eck & T. de Jong 1999).

Analysis based on the concept of accessibility is therefore ideally suited to be integrated with GIS. Traditionally, a GIS user has to approach this kind of problem with buffer and overlay tools, sometimes combined with Thiessen polygons (T. de Jong & J.R. Ritsema van Eck 1996). Geertman and Bosveld (1990) used potential values based on a transport network, which can be seen as a first attempt to incorporate some accessibility analysis into GIS.

2.5. Alternative Methods for Measuring Accessibility

What are needed are the approaches to translating the concept of accessibility into measures of accessibility that can be used to quantify the accessibility, which would give planners and decision makers a powerful tool for determining the need for and the effectiveness of alternative land-use and transportation policies.

The spatial accessibility can be measured through route distance, travel time, and travel costs. Accessibility is distinguished between composite measures, comparative measures and time-space approach (Robinson 1990). The measures also classified into observed-travel/attenuation measures, objections to travel demand-based measures and objections to potential measures (Breheny 1978). K.T. Geurs and J.R. Ritsema Van Eck (2001) review accessibility measures grouped by the different perspectives on accessibility for their ability to evaluate its impacts. They identify three basic perspectives on measuring accessibility and several accessibility measures derive from these perspectives in his case study.

Accessibility measures can be organized into four types:

2.5.1. Distance measures

The simplest of distance measures is the “relative accessibility” measure. It is defined as the degree to which two places or points on the same surface are connected. The simplest measure of relative accessibility is the straight line between two points.

A distance measure is a very simple accessibility measure combining the location of an activity with the transport system. The measure can be used if the destination is known, e.g. in the case of a visit to a town hall. If more than two possible destination are analysed (the accessibility of one place of point to all other places), a contour measure can be derived (K.T. Geurs & J.R. Ritsema Van Eck 2001).
2.5.2. Contour Measures

The contour measure, also called a ‘proximity count’, ‘proximity distance’, ‘cumulative opportunities’, ‘isochronic measure’, indicates the total number of destinations reachable within a given travel time or distance and does not discount opportunities over distance. I.e. This measure emphasizes the number of potential destinations or opportunities rather than their distance.

\[ A_j = \sum_{j'} D_j \]  

(Formula 2-1)

where \( j' \) is the overall locations that the distance from which to the origin less than a threshold value, \( D_j \) is the number of opportunities in location \( j \).

Early studies modelled accessibility as cumulative functions of opportunities that could be reached within a predefined time. Later, many authors analysed accessibility by using contour type of measures, including analyses of accessibility of jobs, population, retail services, public services, health services, education and recreational facilities.

The main advantage of the measure is that it presents an easily explainable accessibility measure without implicit assumptions about a person’s perception of transport, land use and the interaction of these two. Furthermore, the data for the measure are comparatively readily available, making it possible to study different kinds of access by different types of people for different activities which are relatively undemanding of data (Jones 1981).

The disadvantages of the contour measure are (a) the implication that all opportunities are equally desirable, regardless of the time spent travelling or the type of opportunity (Vickerman 1974). (b) the arbitrary selection of the isochrone (or isodistance) of interest and (c) the lack of differentiation between opportunities adjacent to the origin and those just within the isochrone of interest (Ben-Akiva 1979). For the evaluation of and use or infrastructural changes this measure has the disadvantage that improvements of travel times may not lead to an improvement of accessibility index. Contour measures aim to describe the transport and land-use system from the user’s point of view. They incorporate the transport component (travel time, cost, and distance) and the land-use component (location of facilities) but do not attempt to evaluate their combined effect of consider the value people attach to each of these components separately (Joseph 1982).

2.5.3. Composite Measures

The best known composite measures are based on the potential values which are related to the gravity model. The gravity model is based on an analogy between the interaction of groups of people and the attraction of physical masses. A potential accessibility measure, estimates the number of destinations within reach using an impedance function for travel distance, time and cost. The measure has the following forms:

\[ A_i = \sum_j D_j f(e) \]  

\[ f(c_{ij}) = c_{ij}^{-\beta} \quad \text{Or} \quad f(c_{ij}) = c_{ij}^{-\beta} \]  

(Formula 2-2)
Where \( c_{ij} \) is the impedance between origin i and destination j, \( D_j \) is the number of opportunities and \( \beta \) is a parameter reflecting distance deterrence.

The measure does not account for the characteristics of the individuals for whom the accessibility is being estimated; all individuals in the same location have the same level of accessibility, despite the fact that they may perceive the set of destinations and travel impedance quite differently (Ben-Akiva & Lerman 1979). Because opportunities are weighted according to distance away, the form of the function should be carefully chosen. It also not is an appropriate accessibility measure for opportunities if competition on those opportunities exists. This method is usually used to measure the nearness of client or potential user to an activity. The disadvantage of the measure is that the accessibility measure is not easily explained.

### 2.5.4. Utility-based Accessibility Measure

A utility-based accessibility measure, describes the utility inhabitants derive from potential accessibility to destinations, using an impedance function for travel cost. It is assume that each destination in a choice set has a total utility and that each individual will select the alternative that maximises the total utility. This approach asserts that accessibility should be measured at the individual level and that the computation of individual accessibility should account for users’ characteristics (e.g. income and demographic variables) in addition to modal to link characteristics (e.g. speed, travel costs) (Banister 2000).

An important advantage of the utility-based measures is that it has a sound theoretical basis, i.e. the random utility theory on which these measures are based provides a direct link to traditional microeconomic welfare theory. Moreover, it takes the individual characteristics into account. But a utility-based accessibility measure is not easily interpreted and that the formulation cannot be explained without reference to relatively complex theories (behavioural models of destination choice or consumer’s surplus) (Koenig 1980).

### 2.6. Comparisons between the measures

For the distance measures, it calculates straight line distances which can not give an accurate description of the reality.

For the contour measures, the key element is the choice of a cut-off travel distance or time. Accessibility levels can be highly sensitive to this cut-off. But the measures do not incorporate an impedance function to weigh opportunities according to their travel time or cost.

For composite measures, a parameter value for the travel impedance function must be selected or estimated using recent empirical data of spatial travel behaviour in the study area, and the measures are based on aggregate travel patterns. Actually, a contour measure is a specific form of the gravity-based measure, with the impedance function equal to one if the opportunity is within the travel time limit, and zero otherwise (Koenig 1980).
For the utility-based measures, they overcome the shortcoming of potential accessibility that represents accessibility of a location or zone, assuming all individuals in the same location have the same level of accessibility. They are applied on a disaggregate level.

2.7. Selection of Accessibility Measure in Analysis of Primary Schools

It is clear that accessibility can be measured and evaluated in a variety of ways. The study focused on applying one accessibility measure to the destination (schools). It is important to choose an appropriate and meaningful approach, as the choice of the selection accessibility measure can strongly influence the result of analysis. Therefore, the context of the selection criteria and actual travel behaviour of pupils need to be detected.

2.7.1. The Behaviour of the home-school trip of pupils

Hukou is a certification booklet of your family granted by the registered residence, the use of which is like identity card and it plays an important role in the selection of public primary school in China. Most of cities in China issue the rule that public primary school and junior high school must recruit students according the residence listed in their Hukou. Normally, only the minority can be exempted from this rule because they can attend a relative religious primary school. The aim of this rule is to embody the principle of attending the nearest school, but some pupils attend school outside the jurisdiction if it is convenient for some reason.

In China, primary education is compulsory education which means the age group of 6-12 years have a right to attend the relevant primary school specified by local education department. For example, in the situation where a pupil within the service area of a school he must go to the school no other choice, say, the distance from home to school 300 or 500 meters, this does not change the accessibility index of a contour measure if the maximum travel distance is set at 500 meters. All residents in an specific area are assigned to the same primary school as their destination. The accessibility of a primary school is based on its location and the trip of the pupils. However, it is often possible to attend a school outside the specified distance if the facility is not cover completely.

2.7.2. The criteria of the selection

A number of criteria can be derived from the above arguments, which can be used to assess the appropriateness of various methods of measuring accessibility:

- Distance decay can be excluded because in this case, i.e. the concept of travel impedance is declined because the amount of distance within 500 meters has no impact on the attractiveness of the schools.
- Measures should be concerned with the need for the accessibility of origins (residents), so capacity of the destinations (schools) must be incorporate.
- The existing available data are sufficient to adopt the measures in evaluation of accessibility.
2.7.3. Contour measures in normative planning

No one best approach to measure accessibility exists. Different situations and purposes demand different approaches. Count measure is one of the most popular accessibility measures do not incorporate an impedance function to weigh opportunities according to their travel time or cost away. This has the methodological disadvantage that one incorrectly assumes that all opportunities are equally desirable, regardless of the time spent in travel or the type of opportunity accessed. The situation is similar with the pupil’s going to primary schools because the pupil within 500 meters must go to the relative primary school without consideration on the distance in reality. The individual data are not covered in the collected data, and this study does not account for the sensitivity to the travel costs (measured by distance) between the different socio-economic groups, i.e. an average cost-sensitivity parameter is used. Therefore, the utility-based measures are not included in the outcome of the selection of measures.

Contour measure is more appropriate. In contrast to the potential value, the contour measure is stable, also in the neat vicinity of data points. More importantly, both the contour measure and its parameter, the distance range, are easily interpreted in real-word terms. In the context of finding a suitable location (or a set of locations) for one or more service outlets, it is not accessibility itself, but the expected number of customers that is the determining factor.

Normative planning methods are characterized by professional or political judgment of the quantity of service that should be provided for a certain proportion of population (Brameley 1986). In the study, the accessibility measure is applied to analyse the accessibility of primary schools for the current situation, the proposed pattern and the plan of the year 2020. The distribution of primary schools influences the level of accessibility to those opportunities. The spatial distribution of the demand for opportunities also influences accessibility, if the opportunities have capacity limitations. So, the capacity of primary schools will be integrated in contour measure to analysis the balance between the demand for and supply of opportunities in the light of the problems stated in the previous chapter.

2.7.4. Data requirements in contour measures

According to the three basic components of accessibility, people, activities and links, the corresponding data needed in this study are shown as Table 2-1. In this research, the population component containing more detail information is used to calculate the demands for school. The transport component covers the bridge between the schools and the students, the geographical efficiency and the demand-supply balance are calculated by the road networks. The activities components include the location and characteristics of schools, which is used to calculate the service area of each school. It also provides an important neighborhood characteristic that is the nearness of other schools.
Components | Data | Purpose
--- | --- | ---
Population | Residential area | Distill origins
 | Population composition | Calculate school-age children
 | Population in street level | Disaggregate population
Transport | Current road network | Build link between demands & supplies
 | Road network plan in 2020 | Calculate distance
Activities | Distribution of Primary schools | Distill destinations
 | Characteristics of schools | Calculate capacity of each school

Table 2-1 Data requirements

Based on the data listed in the Table 2-1, we can give a detail accessibility analysis in the study area with the aid of contour measure and GIS.

2.8. Conclusions

In this section we give a picture of the practice of urban planning in China and review several accessibility theories conducted in public facility planning. This review of the selection a count measure method in accessing accessibility follows the framework shown in Figure 2-4, which also includes the data requirements in contour measures.

![Figure 2-4 Framework for the review](image-url)
3. Background of Study Area

3.1. Introduction
This chapter is a general description of the case study area, including the presentation related to the urban master planning. In this part, data collection and research scope are also involved.

3.2. Study Area

3.2.1. Changsha City
Changsha, the famous city in the Chu and Han with a history of over 3000 years, is the provincial capital of Hunan, located in the beautiful and richly endowed river-valley plain in the southern-central of China (see Figure 3-1). It is bounded by 28°2′ to 28°16′ north latitude and 112°53′ to 113°6′ east longitude. The city is the political, economic and cultural centre in Hunan as well as the backing centre to develop Dongting Lake area of Yangtze River Development Zone in China. Xiangjiang River and Liuyang River cross the city.

Changsha has achieved grater successes in the economic contraction and social development understanding along with economic reform and opening to the outside world since 1978. The city ranks the 19th among the 50 strongest cities in the comprehensive economic strength in China, which was published by the state. Changsha also has well developed commerce. It has served as the gathered place of merchants and the collecting and distributing centre of commodities since ancient times. The city is the site of HuXiang culture that is one of the three major culture genres in China. Education, science and technology in Changsha are developing rapidly. At present Changsha have 3361 schools and colleges of various kinds with 1,137,000 students including 23 colleges and universities with 72,000 students.


Changsha has jurisdiction over Yuhua, Furong, Tianxin, Yuelu and Kaifu districts, Changsha, Wangcheng and Ningxiang counties and Liuyang city. The total area is 11,819 square kilometres including 554 square kilometres of metropolitan area (the area in and between the built-up area and the surrounding environment) and the total population stood at 5.83 million of whom 1.90 million were non-agriculture population (2000). The primary school children are 466,500 in the whole city. The age composition of the population in this city is shown in Figure 3-2, which essentially illustrates the biggest part population group are about 20 and 35 years old and another climax of primary-school age children will come.

Figure 3-3 shows the steady growth of the total population and pupils in the metropolitan area of Changsha city from 1994-2000 and the forecast is from 2010 to 2020. The population forecast is based on four aspects forecast: birth growth, urbanization, non-agriculture population and urban size, assisted by CPPS (Chinese Population Projection Project System) software (Population statistics theme from Changsha urban planning institute).
Figure 3-1 Location of study area

Location of Changsha in China
Location of Yuhua district in Changsha

Figure 3-2 Population pyramid of Changsha (1999)
3.2.2. Yuhua District

Changsha municipality is made up of five districts: Yuhua, Furong, Tianxin, Yuelu and Kaifu. In this research, allowing for the time, the availability of the useful data, the study area is focused on Yuhua district, also because it represents a growing big size city with a diversity urban configuration. As shown in the right map of Figure 3-1, the district stands in the southeast of Changsha city covering part of the city centre and suburban with the total administrative area of 115.2 square kilometres. The total population has reached 0.50 million at the end of 2000. Figure 3-4 shows Yuhua district is comprised of nine streets. These streets ranged from about 28,264 populations (Lituoxiang) to 111,933 populations (Yuhuating), and from just 1.70 square kilometres (Houjiatang) to 45.52 square kilometres (Dongjingzhen). The north of Yuhua district shares part of the city center while the most part of the south and east are rural area with less populated.

As the Southeast Gate of Changsha city, Yuhua district is well known as an intersection to link Changsha, Zhuzhou and Xiangtan, three large cities in Hunan province, with two thoroughfares extending out. Yuhua district has a solid industrial basis on manufacturing. Within the district there are several large-scale state-owned enterprises. It also has a good urban traffic network and a developed intercity transportation. Within the district, there are Jing-Zhu (Beijing to Zhuhai) express way, railway and two trunk roads running through in the north-south direction.
The national educational policy of providing compulsory education to all children aged from 6 to 12, the population in this group is 39981, which yields approximately a rate of 80 pupils to 1,000 inhabitants in Yuhua district in the year of 2000.

3.3. Scope of the study

Totally, 57 public primary schools and 1 private primary school are located in Yuhua district. The private primary school aims its customs at the high income group people whose children travel to school without a limitation within a fixed radius, but the tuition is expensive. The plan of the government has not take the private primary school into account, which due to several possible reasons. First, the unaffordable tuition to most people result to a small quantity of pupils recruited; Secondly, the number of private primary school is finite. Approximately, only one private primary school is located in each district in Changsha city. Thirdly, the closure of the private school is at discretion of the board chairman of the primary school according to the amount of profit. As mentioned above, distance limitation plays an important role in the selection of primary schools, which have no impact on the private primary school where lesser consideration for travel because lodging is required. In this study, only public primary schools are treated.

In this research, accessibility measures based on a single purpose trip correspond to multi-purpose trip where the accessibility of a primary school is based on the distance from its location to residence not relative to the home-work trip of the children’s parents. It is known that the children’s trip to primary school is always accompanied by parents, especially to the low grade children.

3.4. Data collection

From the data requirement (see 2.7.4), it is necessary to collect data from a number of different sources. The data on the number and location of the primary school were obtained from the Changsha municipal planning and design institute’s Middle and Primary School Plan in Metropolitan Area 2020. The distribution of the existing primary schools and the planned primary schools are from the relative files of the plan. The land use, roads networks, topographic maps and some national standards are derived from this institute, too. The boundary and the population files for census and for the street network of Yuhua district were extracted from the Census of Population Reports in 2000, the published information of the Fifth Population Census of China (the most recent), from the Changsha Statistics Bureau. The smallest available statistic unit of the population data is street level. The data about the characteristics of schools are derived from the Changsha Education Bereau and Yuhua district branch, others from Internet.

In Figure 3-5, the data used in this research can be categorized in two parts: spatial data and non-spatial data. The lighter colour in this figure means the data from affirmed source and the darker colour represents the data estimated to describe the main transport mode of school-age children (see section 3.6).
3.5. Land Use

The spatial distribution of land use activities and the level of service of the transport system determine the amount of access people have to all kinds of activities (e.g. education) and thus influence people’s social and economic opportunities.

3.5.1. Land use in 2000

As Figure 3-5 shows that the yellow representing the residential land in Yuhua district in 2000, which does not cover the settlements in agriculture land. They are scattered within Yuhua district and many of the residential land is mixed with other land. It results in the less efficient use of urban infrastructures and facilities. The quality of environment in this residential area is poor for the influence: noise and dust from other land used, such as commercial, industrial land. It can be seen from this map that rivers, lakes and railways, highways pass through this area too. All of these are unsafe elements for children’s travelling to school.

3.5.2. Master plan 2001-2020

Urban planning is perceived as a tool to realize the socialist ideology of planned development and to translate the goal of economic planning into urban space. A master plan is a long term strategic layout of the city. In 1993, China State Department authorized Master plan of Changsha (1990-2010) which legalizes the actions of urban planning and presents a blueprint of future urban construction. In 2001, Changsha municipal government decided to amend the master plan and brought forward the amendatory scheme of urban master planning, because the current city size (population and urban built-up area) had exceeded estimate of the plan in 1990. Furthermore, the development of the densely-populated Changzhutan agglomeration (the areas in and between the three largest cities-Changsha, Zhuzhou and Xiangtan) is incorporated.
The Master plan of Changsha (2001-2020) including land use, transport plan and other thematic plans, have been developed by the Changsha municipal planning commission. These plans contain land use developments and changes in the supply and use of road infrastructure with the context of long term economic developments from the Changsha municipal government for economic development analysis on the outline for the Tenth Five-Year and Strategy for Urban Development in middle and long term. The plan pointed that Changsha was a famous historic city and it was the political, culture centre of Hunan in the past. In the future Changsha would be planned as a modern city with the commercial, cultural, scientific and educational, information centre functions.

This master plan indicates the target size, the economic orientation and structure and the spatial structure of the city, so a master arrangement of the residential land use of Yuhua district in the future is described. The population forecast is 790 thousands people in the year of 2020 with a pupils number of 63180. From Figure 3-7, we can see the residential land distribution in Yuhua district to 2020. Comparing with Figure 3-6, urban land is planned according to the plan structure “residential district-residential quarter-housing cluster”, which makes the residential land relative concentrated and makes it convenient to arrange urban facilities and infrastructures. But in master plan, only the first level, residential district is presented and the other levels in detail plan.

3.6. Assumptions concerning transport mode

The road network reflects the cost of moving from one point to another. Delineation of a route and the cost of moving along this route depend on the mode of transport. In Shanghai city in China, 87.08% students select walking as their first choice to school and the 95% people select walking when the travel distance within 1000 meters (Shen Jianwu & Wu Ruiling 1996). Changsha has a smaller city size than Shanghai so in Yuhua district, walking is the most common means of travelling to school considered as main transport mode for pupils. The enrolment of primary school must base on the nearest distance to school, which is control by using the residence listed in their Hukou booklet as identification. The main customers of primary school are children, 15% of them are accompanied by parents.
Figure 3.6 Land use (2000)

Yellow—Residential  Red—Public Facility  Blue-black—Industrial
Azury—Water        Green—Green space    Other—Miscellaneous

Figure 3.7 Land use (2020)

Yellow—Residential  Red—Public Facility  Blue-black—Industrial
Azury—Water        Green—Green space    Other—Miscellaneous
4. Data preparation for Analysis

4.1. Introduction

The previous chapter gave a description of the study area. The present chapter is to prepare data for analyzing the accessibility for the current distribution and plan in 2020. This is a separate part because it is an important section which determines the accuracy of results. This part is carried out using two major steps: data pretreatment and data preparation, the former is a preparation for the latter in terms of the relationship between these two steps.

4.2. Data pretreatment

Since all the original maps are in different form (.dwg or .tif), which are hard to process in the GIS software for spatial analysis, necessary digitizing, refining and converting are conducted to ensure the uniformity (see Figure 4-1). Digitizing is needed to extract the information, such as centerlines of roads, boundaries of residential land. The associated attributes are entered into the database. Furthermore, the spatial data refer to thematic maps of road network, residential locations, land use and locations of the primary school but the original data in the form of .dwg include too much information and some of which are not needed in the study. So, the pretreatment of the data also includes data refining. Some of the data, such as road networks and water system cover outside the study area, which needed to be confined. Besides, most of them are of different spatial unit, and it is important to pretreat them into the right form.

Before data analysis, firstly, the spatial data were examined to explore the reliability of data or whether there were complete, because spatial analysis is key part of the research. Residential land in 2000 only covers the urban area and the agriculture settlements are neglected, but the agriculture population also the demands for primary schools. So there is a big gap between the current residential land and the reality, the topographic map is a reference to rectify the residential data.

![Figure 4-1 Data pretreatment](image)

4.3. Process of data preparation

According to the data requirement in section 2.7.4, three aspects data on origin, transport and destination are prepared for the following analysis. The relationship between the steps is portrayed in Figure 4-2.
4.4. Data on demands

For accessibility analysis, it is essential to quantify demands for a range of services and population (actually the school-aged children) are seen as the proxy of the demands. The available data, statistics on population distribution published, at the level of administrative statistical unit street are not as detailed as needed.

4.4.1. Subdivision of the neighbourhood

Subdivision of the neighbourhood into tessellations is an indication for the spatial distribution of demand by using a more accurate population data; moreover, furthermore they provide a better image to interpret the outcome of analysis as an almost continuous pattern that reflects gradual changes in space. The total number of inhabitants in the study area amounts to roughly 0.50 million at the end of 2000. Normally, there are two artificial forms to subdivide the neighbourhood: squares and hexagons. Someone also use another form, blocks to subdivide neighbourhood. The selection of the form lies on the size of total area and the request of precision. In order to get a more accurate result, hexagons are selected in this study to interpret. The reason can be seen from the comparison in the following. The centre point of the sub-area represents the attributes of the polygon. Therefore, a farer distance from centre to edge is a disadvantage for the square tessellation to present than a hexagonal tessellation whose shape is close to circles and the distance from each tile to all its neighbours is the same, but circles can not fill the whole area completely as a result of margins between circles. Using the block as the tessellation can not give an accurate picture of the catchment area. Most important of all is block unit can not incorporate the unsafe aspects, such as highways and railways. Etc.

A balance should be found between the need for very many small tiles to represent best a continuous surface and the need for swift results as this is inversely related to the number of tiles. Geertman and Bosveld (1990) opted for close to 30,000 tiles but Toppen and T. de Jong (1992) showed that acceptable results can also be reached with a much smaller number, like 1,000 tiles. In this research, the study area is tessellated into well over 13000 hexagons and the straight-line distance between the centroid of two hexagons is 100 meter. So approximating a continuous representation of space instead of a discrete one is prepared for the analysis.
4.4.2. Population disaggregation and forecast

The hexagons have been constructed in previous step but there is still short of associated population attributes. The school-age children are the demands which are set using overall the ratio of 80 pupils per thousand inhabitants (Hunan province educational standard for middle & primary schools, 1993). At first, a basic requirement is a more detail information on inhabitants. The census data of 2000 is considered as a main basis to investigate the spatial distribution of population.

In the absence of information about individual pupil address, GIS spatial analysis techniques and attribute operation may be of use as an alternative to the calculation of detailed population. The collected data in street level are distributed to each hexagon by taking the hexagonal area in the residential land as weight, based on the assumption that the population distribute evenly throughout one street so the density is uniform. A partial hexagon will be assigned population by prorating the area on the basis of area percentage. The proportion of any residential land area falling within a street is computed after intersect operation. This proportion is then multiplied by the population density in this street and the product will be subdivided by the hexagons. Similarly, the population of each hexagon can be calculated. By representing the addresses of pupils as centre points on a map, the customer dispersal can be distinguished. More than 4000 hexagons representing population information left as the demand point. Better accuracy may be achieved by exacting demand location, i.e. pupil addresses as points in the network analysis. If the centre points are located within a user-specified distance, they will be captured to presents the population attribute of hexagons.

The city is expanding and the population density is changing. After 20 years, there will be a striking change in Changsha city, also in Yuhua district. The land use will progress in the instruction of the master plan towards a more concentrated pattern and population will increase, maybe as the forecast of government (see Figure 3-3). In order to analysis the accessibility of the plan in 2020, the forecasted population in detailed level is also needed. The total population in Yuhua district of 2020 years is amount to 790 thousands according to the forecast of government. The figure is based on four aspects forecast: birth growth, urbanization, non-agriculture population and urban size, assisted by CPPS (Chinese Population Projection Project System) software (Population statistics theme from Changsha urban planning institute).

Figure 4-3 gives a general description of the disaggregation process. The process should be made carefully as it could be a major source of accumulated error which can end up with misleading results. It should be mentioned here that after disaggregation, the check for the sum of population is necessary. During the step “selecte by location”, a 50-meter buffer search to the feature is applied, which is the distance from the centre point to the hexagonal edge, so there is a gap between the circle sharing a same centre with the hexagon and the six corners of hexagon. A decrease of residual is needed for a balance. Figure 4-4 is a contrast before and after the subdivision.
Figure 4-3 Process of population disaggregation
4.5. Data on links

In this study, roads are the links between the demand and the destination. Dummy roads are of great importance in this study, in terms of technical aspect and unsafe consideration.

As T. de Jong said in 1991, most GIS software only allows network analysis when both origin and destination are part of the network. This makes it impossible to perform any calculations for locations not linked to a node in the network. This limitation makes a highly detailed network necessary in order to avoid such problems. Origin and destination are in separate maps and are linked to the closest node or arc in the network when distances are calculated. This will be conducted in the next section. Another advantage of this method is that one transport network can be used for a great many different applications.

The significance of incorporating the unsafe aspects can be seen from the following figure. Walking is the main transport mode to children. Every year, 18500 children below 14 years old die of traffic accident in China. This figure is 2.5 times of the death rate of European. Martin Eichelberger, President and CEO of Safe Kids Worldwide, believes that traffic accident is the second killer to children death less than the first, drowning. (http://www.39.net/hotspecial/ztbd1/lm1/36783.html, last accessed in August 2, 2004)

There are also some unsafe elements in Yuhua district, railway, highways and river while the road data only provide a general description of the existing situation including highways, main roads and branch roads. Dummy roads, as portrayed in Figure 4-5, constructed by the triangles, define the foot-paths wherever possible, connecting the centre points of hexagons with a distance of 100 meters are the supplement to the roads of the land use map in this case. It is necessary to remove some streets from the network for safety and practical reasons in dummy roads because it is not a good idea for school children to walk to school along an interstate highway, nor is there any home on these roads, so river, highway and onramps are excluded in the network, displayed as the cut in Figure 4-5. So, the
physical roads which are irregular lines in the below figure, companied with the dummy roads, constitute the road network in study area. The shortest travel distances are computed from the place of residence to the primary schools along this road network.

![Figure 4-5 Road network and dummy roads](image)

4.6. Data on destinations

Destinatione is the facility that provides opportunities in accessibility analysis. Here, the primary school is seen as the destination.

4.6.1. Converting boundaries to centroids

The distribution of primary schools includes the boundaries of schools, so translation of polygons into their centroids by using the Convert Shapes to Centroids in ArcView is needed to prepare for network analysis.

4.6.2. Computing capacity

In fact, a primary school capacity depends on factors such as the availability of space, building area, playground and staffs while in the context of quality, the quality of teachers, and the availability of books or computers are seen as references. In this study, a simple multiple criteria evaluation is used and there are three main criteria in estimating the service capacity of each primary school.

- Availability of space
- Availability of teacher
- Existing number of class

According to Changsha educational standard for primary and middle school in 2001, the standard of the criteria is shown in the second column of Table 4-1. This table also give the weight of each criteria. During the process of urban expansion, the space of school is limited especially in the city centre where have a high density of school distribution. As mentioned in section 1.2, one of the current problems in the city is a too limited space for schools. Provided there is enough space, sufficient classroom and playground can be built to accommodate students. Teachers are easier to redistribute among pri-
mary schools, so a higher weight is assigned to the availability of space as 0.6 and other criteria has a lower weight.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Standard</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of space (A)</td>
<td>15 m²/student</td>
<td>W₁ = 0.6</td>
</tr>
<tr>
<td>Availability of teacher (B)</td>
<td>24.1 students/teacher</td>
<td>W₂ = 0.2</td>
</tr>
<tr>
<td>Existing number of class (C)</td>
<td>45 students/class</td>
<td>W₃ = 0.2</td>
</tr>
</tbody>
</table>

Table 4-1 Criteria and weights to compute capacity

The calculation adopts the following forms:

\[
\text{Capacity} = (W₁ \times \frac{A}{15}) + W₂ \times (B \times 24.1) + W₃ \times (C \times 45) \quad \text{(Formula 4-1)}
\]

Where, A, B and C present the criteria respectively in Table 4-1. Based on Formula 4-1, the capacity of each school is computed listed in Appendix 1.

4.7. Conclusion

In this part, GIS offers excellent possibilities for storage, spatial analysis and presentation data, especially, provides the tools for disaggregating data. In the light of data required of contour measure, this chapter focuses on three aspects data on origin, transport and destination and describes how to preparation data for accessibility analysis. The data on both spatial distribution and capacity are prepared for the analysis on the next chapter.
5. Analyzing Accessibility to Primary Schools

5.1. Introduction

The data have been prepared in the previous chapter. This chapter is to apply the accessibility measure for the current distribution in order to develop a methodology to describe and improve the accessibility in the study area. The plan of the year 2020 is also involved.

In the case studies, the selected accessibility measure, contour measure, is applied to the destination (schools). To achieve the main objectives, as a detailed supplement of research flowchart in Chapter 1, the research methodology is carried out from two perspectives.

5.2. Flowchart for analyzing accessibility

Responding to the problem statements in Chapter one (see Figure 1-1), the accessibility analysis is carried out from two perspectives: spatial distribution and capacity, generally described in Figure 5-1.

![Figure 5-1 Flowchart to analyze accessibility](image)

5.3. Analysis on spatial distribution

The main purpose in this section is to take a spatial analytical perspective to analyze the accessibility in terms of the shortest distance to the facility. The capacity will be discussed in the next section.
5.3.1. Calculation of the distance between demand and supply

After data preparation, the demand is the number of children living in the residential land. The road networks are represented in the network as linear features and schools are supplies represented as points. Then the shortest travel distance along road network is computed in order to give an accurate picture of the node distance between the destinations and demands. In many researches, the distance between the centroids is calculated as the straight-line distance. In this study, we estimate the distance based on network distance (the shortest path distance along network). This sort of distance is the most appropriate for our purpose for a more actual description of reality.

Figure 5-2 summarizes the process of distance calculation, road network is the link between the origin and the destination, but not all the origins and the destinations are exactly on the nodes in the road coverage. In ArcInfo, spatial relationship of roads can be described as linear network. The GIS stores a network as a set of line features with associated attributes and it is suitable for automated calculated distance. The attributes associated with the topology of links and nodes make it possible to model real world flows through all kinds of channels.

At first, the population and the schools regarded as supply points and demand points have been linked to the nearest node in road coverage with a search radius of 150 meters. Secondly, the network distances between all the selected nodes in the network coverage by specifying a search radius, to limit how far to search around each node. Using the school as the center, demand point as the stop for search and length as the impedance, in the output access table (see Figure 5-3), an origin-destination table is constructed. The cost of traversing the shortest path along the road network between the two nodes is calculated. Thus, the distance between a centre and a target location is the sum of three distances:

- The distance from the centre to the nearest node on the road network: a straight-line distance.
- The network distance from the node nearest the centre to the node nearest the target location, and
- The distance to the target location from the nearest node on the network.

The access table is the result for computing distance and also is an important link for the residents and the schools. The field have an A and a B appended to the item name means that A refer to the from or origin nodes, schools; B refer to the to or destination nodes, residents. Network field is the distance between the two nodes, the cost of traversing the shortest path along the street network. From this table, the information on how many people have a link to school within a specific distance is captured based on join of attribute tables and selection of values that are hooked up to that destination.
### Figure 5-2 Process of distance calculation

- Dummy.shp
- Roadcenter.shp
- Merge
- Origin.shp
- Walksupport.shp
- School.shp
- Convert to coverage
- Origin.point
- Road.arc
- Destination.point
- Build
- Near origins to roads node
- Search-radius=150m
- Near destinations to roads node
- Nodedistance
- Access table1

### Figure 5-3 Access table of distance calculation
5.3.2. Identification of serviced and unserviced area

Serviced area is within the specified distance to facilities while unserviced area defines as the area where people must travel more than specified distance to the facility. A colour map will come into being as a result of different level distance from residence to facility.

As mentioned in chapter two, the key element of contour measure is to choose a cutoff travel distance or time. Impedance is the cost associated with the utilization of the supplied resource through a network. In this research, the distance to the school is the impedance to the utilization of the destination. The Chinese country standard, 500 meters service radius will be regarded as the cut-off, which accords well with the reality, as we will later see. Children who live on streets from which the travel distance to the school exceeds the specified maximum will not be incorporated as the serviced. In fact, the student living on a street farther than 500 meters from the school will be assigned to that school for no other choice. In reality they attend the school with a farther distance than 500 meters. Identifying service area and under-serviced area will base on the catchment area covered by 500 meters travel distance. Integrated with the attributes of the hexagons, the population within the under-serviced area will be calculated. Because there are several hexagons that count for more than one school, the population in serviced area can be computed by subtracting the total population by the population in unserviced area, correspondingly, the number of pupils that are within specified distance or not from each school is counted. It is a sort of index to score the performance of accessibility. Another distance, maybe 600 or 800 meters also can be specified to identify serviced and unserviced area in order to support decision making.

In this step, an accessibility measurement named contour measure is applied to add up all the pupils that live within or out of the given distance. Competition between service centres is not taken into account. In this case, the centre points of the hexagons representing the number of pupils will be summed. The extent of the advantage or disadvantage in terms of distance is measured by coverage percentage, which is to determine what proportions of demands are within the specified distance to the existing facilities.

Note that there are several settlements in overlapped area, which count for more than one school so allocation the pupils to the nearest is necessary. It is impossible to compute the population in overlapped areas for more than two times because to public primary school, one pupil is assigned to one school. In the following step, allocation of pupils will be conducted before the comparison between the capacity of the school and the demand is implemented.

5.4. Analysis on capacity

It seems like that the residents in oversupply area can choice school, but in fact, the attending to school is based on the limitation from Hukou. In reality, the conclusion that most of the school-age children attend primary schools is drawn from the enrolments ratio, 99.99% of 2002. Unfortunately, some of them have an inconvenient long trip to the facilities. Lack of the detail information on the address of pupil results to an assumption that allocation pupils to the facilities based on the capacity is a referenced description of the optimal assignment of pupils. Moreover, both the allocation operation and the Hukou policy are based on a nearest visit to primary school. The allocation of pupils also give
the government a suggestion about how to divide the school jurisdiction because it is impossible to add several new primary school within a short time and equip with enough teachers and facilities. Furthermore, this is a practical method to reduce the travel distance from residence to school.

The following sections discuss allocation modelling in connection with the process of assigning children from their residential location to the nearest school. In this step, the demand and the supply is the same as the calculation of network distance from the origin to the destination. GIS software package also provide allocation modelling as a specific type of network analysis. When a pupil is assign to the center, the available supply at the facilities is diminished by the pupils’ demand. The allocation ceases when the center supply is exhausted, which is to say, allocate will assign the pupils, as the proxy of demand to the center until the total number of pupils equals the available supply of seats at the school. This kind of spatial analysis provides the means for quantifying the relation between school location and capacity on the one hand and the demand for seats in the surrounding areas on the other hand. The comparison the capacity with the demand and a balance will be conducted based on the results in Chapter 6.

5.5. Towards a higher level of accessibility

Allocation of pupils cannot lead to a thorough solution to the problems. In this part we will look for suitable sites to locate new primary schools in Yuhua district. The heart of this process must base on two aspects considerations: cost and coverage percentage. Moseley (1979) believes it is important to realize that this inevitably means seeking the best compromise between three incompatible goals:

A high level of accessibility

Low cost

Complete geographical/social coverage

Figure 5-4 Goals for a higher accessibility
(Source: Moseley 1979)

He terms the process as the dilemma of accessibility planning because if low cost has been achieved then at least one of the other two goals must be sacrificed. In this research, a compromised method is used as the following.
After identifying the serviced and unserviced area, the facilities within the overlapped area are also identified. As mentioned above, the oversupply is not benefit to utilize facilities fully, so we need close some facilities in the overlapped area before adding new facilities. Or the facilities should be allocated to the unserviced area in view of access equality. In order to compare the result clearly before and after relocating schools, we select some primary schools to close then add same number ones. That is to say, the total number of primary schools is identical before and after allocation of facilities. The number of facilities in overlapped area will decrease while some will add to unserviced area. So the facilities in overlapped area are seen as candidates to close while the unserviced area identified by the reserved facilities, can be seen as candidate sites to add new schools. That is to say, the total number of facilities is still 57, but the performance is different (see 6.3.1).

5.5.1. The criteria of closing primary school:

- The primary school should have a distance within another within 500 meters
- The primary school should locate in the overlapped area where people have more than one choice.

In order to close the facility in overlapped area, the first step is conducted by identifying which facility answers for the criteria above. Another access table (see Figure 5-5) is as a result of calculating distance, which is based on both the centers, and stops are destinations (schools) and 500 meters as the cut-off to compute distance. Following the procedure described in 5-5, the destinations to be deleted and reserved are found out.

![Figure 5-5 Identify the destination to be deleted and reserved](image_url)
Based on the reserved destination, the new unserviced area is identified.

5.5.2. Add new primary schools in unserviced area

The hexagons in unserviced area are computed distance to each other by using themselves as both centers and stops to find out the hexagon that have the maximum links to each other within 500 meters, where the more links to a hexagon, the higher accessibility to it in terms of distance. Except for the number of links, the population in the hexagon is the second parameter to select the hexagon as location. This selection is because the rural area is always given a discriminatory treatment whereas in the urban areas, better facilities have been provided (Moseley 1978, K. Naresh 2003). The case is same as Yuhua district, as you can see in 6.2.1. Such a central point is regarded to have a higher accessibility than a side one in the light of travel distance.

According to the count of the links, a priority area to add new primary school is identified, which includes too many candidates. Then the reselection is implemented based on the population in the hexagon. Finally, the new primary schools are selected.

5.5.3. Identification of serviced and unserviced area

Measuring how far the allocation distribution might improve the accessibility for those in need of the facility, the performance of the allocating primary schools will be scored. After merge operation to the reserve destinations and the new destinations, an identification of serviced and unserviced area process will be operated again.

5.6. Discussion and conclusion

The approach makes use of contour measures to calculate the number or population. Contour measure is a simple count, in which for each site the number of population that are within a specific distance is calculated. The calculation based on Formula 2-1 (see 2.5.2), as the following:

$$A_i = \sum_j D_j$$

In this study, $j^*$ is the overall locations that the distance from which to the origin less than a threshold value, 500 meters, $D_j$ is the number of residents in location $j$. This method does not discount opportunities over distance. When the distance to the nearest 100 pupils is 300 meters the measure does not discriminate between a site that has the first 80 pupils at 200 meters and a site that finds the first 20 pupils also at 200 meters away. It only measures that there are 100 pupils within 500 meters.

Contour measures are similar to buffer analysis someway. In contrast to using the more straightforward GIS buffer analysis, the benefit of this method is an incorporation of the current situation, the non-uniform character of the area, such as unsafe aspects, and an easy interpretation of the map. If using travel time as impedance, the quality of the transport network can be incorporated. It also provides an easy way to demonstrate the improved situation and make a simulation which will be described in the section 6.2.2. This is the biggest difference with buff tool in GIS. Furthermore, unlike regular GIS buffer analysis, they provide an overall view of accessibility by a continuous pattern reflecting gradual changes in space.
GIS provides strong ability in spatial analysis, attribute calculation and data presentation. Graphical presentation of the results and analysing data form a different perspective improve the insight in problems and make decision-making faster. This section also presents a process to identify those areas that are serviced and those areas that are unserviced, so, the number of people who have a higher accessibility and who have a lower accessibility to primary schools can be estimated before and after adding new schools. Issues concerning school capacity are considered in the analysis. All the demand points and destination points are linked by access table. T. de Jong highlighted the importance of access table in the summary of the relationship between proximity counts (contour measure) and catchment areas in 1991, as Figure 5-6. This chapter is a methodology preparation for the coming chapter, a detail analysis of the result.

![Figure 5-6 Proximity counts and catchment areas](Source: T. de Jong 1991)
6. Results and Analysis

6.1. Introduction

After development of the analysis methodology, analysis of the result for accessibility will be carried out in the following. The results are compared in order to investigate if the developed method is an effective way to evaluate accessibility and to make suggestions towards higher accessibility. The results are divided into two parts: the first one begins with a discussion on the existing accessibility to school, followed in the second by an in-depth analysis of the proposed pattern. The same analysis for the plan is next examined in the second part. These patterns are treated from two aspects: spatial distribution and capacity. The former is to illustrate the accessibility in terms of distance and the latter is to find out the demand-supply relationship.

But in this chapter, there will be an emphasis on the analysis of the existing accessibility to primary schools for the absence of enough data about the neighbourhood of the plan.

6.2. Analysis of the existing accessibility to primary school

Figure 6-1 shows the results for calculation of the distance between the demand and the destination. Different tune color indicates different distance to the primary school. Figure 6-2 presents a global overview of the residential area of Yuhua district. In which polygons coloured by varied transparency represent different streets. Integrated with this map, from the existing distribution of primary schools in Figure 6-1, we can find out that a few facilities cluster scatters in northwest part of Yuhua district where population density is high. The people in these areas have more opportunities to access school. The distance from each hexagon to primary school is consistent with the distribution of facilities. It is clearly that in urban area, children travel shorter distance to school than those in rural area. The analysis of existing accessibility is based on analysis of the coverage percentage, the capacity of school.

6.2.1. Coverage percentage

According to the procedure to identify the serviced and unserviced area, described in section 5.3.2, coverage percentage is defined as:

\[
\text{Coverage} = \frac{\text{Population in serviced } \text{ unserviced area}}{\text{Total population}} \times 100\% 
\]  

(Formula 6-1)

Formula 6-1 is an index to see how well the facility performs in terms of distance. In general, the higher the coverage percentage is, the better accessibility as for distance. But to the percentage in overlapped area, for one choice is benefit while for two to four is cost. Because as far as the children stakeholder is concerned, this overlapped supply is benefit. But to the government, the percentage of
the population who have more than one school choice is a cost, which results to fail to utilize public facilities sufficiently and a high expend compared with so many children in disadvantaged areas.

In contour measure, the selection of cut-off is important. According to the current government standard for planning primary school, the service radius is 500 meters. In Figure 6-1, we define the cut-off equal to 500 meters and select the hexagons within this distance to school as serviced area. Of course, if the government want to revise the serviced radius for primary school, the cut-off can be selected as 500 or 600, etc. meters to compare in order to support decision-making. The serviced area is distinguished from the unserviced area, which is as a result of this cut-off, shown in Figure 6-3. The boundary between the yellow and the blue define the catchment area which represents the actual relationship between supply and demand. The yellow represents the residents have one primary school to choose while the darker yellow means the overlapped catchment areas, oversupply area, where people have more than one choice by using different yellow tones. It is evident that some schools share part of area with a near one. The centroids of hexagons are caught to represent population information, which is the basis for the assessment of performance: coverage percentage on accessibility. The map clearly shows that most unserviced area is located at the periphery of the city.

Figure 6-1 Distance to primary school
Figure 6-2 Overview of Yuhua district residential area

Figure 6-3 Serviced area and unserviced area
Contour measure is used to grade the performance and the result represented by coverage percentage. Table 6-1 gives a summarization of the total number of residents in serviced area and unserviced area respectively. In total, the existing facilities system provides 58% of the total population within 500 meters. It can be seen that the children in Gaoqiao, Lituoxiang, Guittang and Dongjinzheng have a farther distance to primary schools and most part of these streets are outskirts of city. They also have the characteristics that the population and housing densities area low in these streets and high in others (see Figure 6-2). Clearly, consistent with Figure 6-1, these three streets are less populated with lower accessibility while other six streets are more populated with much higher accessibility. Rural areas have always been given a discriminatory treatment as mentioned in section 5.2.2. These figures also clearly indicate that primary schools in these streets are the most disadvantageous in location, less accessible. In the urban area, we have better access to facilities. For example, the children in Lituoxiang Street have the lowest accessibility to primary schools and the unserved percentage shoot up to 86%. Dongjinzheng Street is only second to it. While in Shazitang Street, the unserved percentage is only 2% and the Houjitang is the second accessible street in terms of distance. This problem is in accordance with the problem statements of chapter one. Due to similar housing and population densities, only minor percentage variations exist between Dongtang Street and Yuhuating Street. It is apparent that the percentages have some relationship with the population density. Based on the educational statistics gazette in 2002, the primary school enrolments ratio is 99.9%. We can make the assumption that each child attends a school so, about 42% of the total population, 209867 residents translated into pupils, 16790 of them travel more than 500 meters to primary schools, the longer the travel distance of pupils, the less advantageous of location for the primary school. Normally, the residents around a school are scored well and have a higher accessibility than those are not.

<table>
<thead>
<tr>
<th>No.</th>
<th>Area</th>
<th>Total Population (people)</th>
<th>Population density</th>
<th>Unserviced percentage (%)</th>
<th>Serviced population (%)</th>
<th>Total Percentage</th>
<th>1 choice</th>
<th>2-choice</th>
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<tbody>
<tr>
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<td>58</td>
<td>37</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

Table 6-1 Coverage percentage in serviced/unserviced area (current)

1. All the percentage in the table means the servied/unserviced population to the total population in the street.
2. Population density: H: >10000 people/km²  
   M: 3000-8000 people/km²  
   L: <1000 people/km²
Not all the high scores indicate good location. The schools near the urbanization area are more accessible and some of them have an overlapped service zone. As shown in Table 6-1, some primary schools have a shared service area, which indicates that the children in this area count for more than one school. In the view of this point, most serviced areas in Shazitang Street are in overlapped area and the percentage of the residents count for two to four schools are 68%. But not all the percentage of population in serviced area is a benefit, the bigger the better. Two groups of outcomes are analysed. The first group covers both serviced and unserviced area and the second group comprises measures of the performance in serviced area where overlapped area are the focus.

6.2.2. Identification of problems on spatial distribution to support decision making

The above is an overview of accessibility in Yuhua district. Three important conclusions can be drawn. One is that the major imbalances of distribution of the existing schools are clearly noticed. Another is a far route result from a big distance to school. Some hints may be emerged about how to improve the accessibility to support the decision making.

Figure 6-4 illustrates the case of Yihuandonglu primary school which is located near a highway and a railway. The red line is the railway and the near black one is a highway with an attribute of road class one. On the left map, the blue hexagons on the left of the school are unserviced hexagons, but they are within the distance of 500 meters to Yihuandonglu primary school. Why do they count as unserviced area? This is the result from the incorporation of unsafe aspects. In reality, children can not walk to school along this highway. In Figure 6-4, they must walk towards north or south to pass this highway from the access, so the travel distance far beyond the specific distance. The right map is a static simulation of building a walking overpass above the highway to curtail the travel distance. The number of population serviced by Yihuandonglu primary school is increased from 2326 to 5169 for the benefit of the walking overpass.

Figure 6-5 reflects a situation where no allocation is imposed and shows the possible reason. The left map portrays the unallocated pupils, represented as seven gray hexagons and located on an islet surrounding by a stream. No bridges above the stream, the dummy roads in the islet, represented by the light blue colour, fail to connect to the whole road network according to the existing situation, as delineated in the right map. Under the assumption that all the school-age children have attended the primary school by means of stepping on the stones shakily in the stream, the reason of the unallocation will be detected. In order to make the facility more accessible and make the route safer, the children require a bridge above the stream.

The above examples are some remarkable examples, which will give the decision maker a support on where and how to improve road infrastructure in emergency. The similar conclusion can be drawn from Zhongnan primary school and Xinshijji primary school for their location near a stream or a river. We can get some hints about how to improve the accessibility and safety of children in disadvantage. According to the components of accessibility introduced in chapter two, increasing the number of primary school is not the only option, adding bus line or improving road condition are choices. The concept of accessibility incorporates not only the origin and the destination, but also the transport link between them.
6.2.3. Comparison of demand and supply in the current situation

Note that there are several settlements that count for more than one location and the closest customer location is allocated to its service center. Under the assumption that the all pupils must attend the nearest school according to their Hukou, the second relevant aspect for the analysis is the capacity. Figure 6-6 shows the catchment area of the service facilities conducted by an allocation model that does not take any jurisdiction boundary into consideration but employs school capacity limitations. According to the destination of the pupils the whole study area is divided into 57 sub areas. It is a reference to the relative government department to subdivide primary school jurisdiction.
Now, every pupil is assigned to the one and only school. Allocation of each pupil uniquely to the nearest school make it is possible to calculate the demand and conduct a comparison between capacity (supply) and demand. In order to describe clearly, an EXCESS index is defined to describe the over-supply as Formula 6-2:

\[
\text{Excess} = \text{Capacity} - \text{Demand}
\]  

(Formula 6-2)

The EXCESS of the each school is listed in Appendix 2. Figure 6-7 counts the schools have excess capacity and those are not, compared with the demand. The EXCESS index is useful to plan capacity of school when we are doing the plan for primary school. The optimal state is the value equal to zero, which indicates the saturation between the demand and supply from schools. If the value above zero means a school has an oversupply, vice versa, we can see from this figure that most of the schools are below zero and have a shortage capacity, but totally, 20 schools out of 57 have surplus capacity compared with their demand. They are oversupply schools (Excess above zero in Appendix 2). To the other schools, maybe have a shortage of space, teachers or desks. It is difficult to achieve saturation between demand and supply at one time. Furthermore, the value sharply on the saturation state is
scarce. It is infrequent that the capacity sharply equals to the demand for school. So, in view of providing finite facilities to the most needed place, we define the values of excess between -2000 and -1000 represent the school need more capacity in emergency. Second to them are the values between -1000 and -500. The values falls within -500 to 500 are acceptable temporarily. The schools with the most excess capacity, whose values are above 500, their corresponding capacity, including teachers, desks, black boards, etc, simply transferred to the needed area.

6.2.4. Identification of problems on capacity to support decision making

In order to find out currently, how well the school satisfy the demand, a comparison between the current student number (source: Yuhua Education Bureau), the capacity of school (computed by the data from Yuhua Education Bureau) and demand for school (estimated by allocation operation) is conducted. The sources of these data are same as the comparison of the proposed pattern (see section 6.3.2).

Figure 6-8 is the comparisons between current student number, the capacity and demand in each school, which is used to investigate the physical condition of school, such as too small space or too big, compared with the current student number. In the upper figure, the contrast of the current student number with the capacity is described. Y-axis indicates the values of students’ number divided by the capacity in school. If the result equals to 1, the current student number amount to the capacity and there is saturation between them. Below 1 indicates an oversupply capacity in terms of the current student number, vice versa. The peak value of the wave is about 2.7 at school 53 (whose FID is 53), which indicates the current student number in this school is almost triple of its capacity. This figure portrays a crowded schooling condition in primary school 53. The case is almost same to school 7. Whereas, the minimum value is about 0.3, the school 55 has an oversupply capacity in contrast to the current student number. We can get same conclusion on school 9, 31, 42, 43. Accordingly, the values between 2 and 3 are the schools needed to improve immediately and from 1.5 to 2 are the second consideration. Both from 0.5 to 1 and from 1 to 1.5 are acceptable.

Similarly, a comparison is implemented between current student number with the demand for school, which is useful to explain the current student number matches the demand or not, shown in the lower chart in figure 6-8. Y-axis represents the values of student number divided by the demand for school. The think line represents the value equal to 1 which means a balance between them. Most student number are less than the demand, which is in accordance with the fact that some students attend private school or attend school outside the jurisdiction if it is convenient for some reason. The remarkable maximum is about 13.7 at school 33, which means this school has too many students beyond its demand. It maybe a high quality school and attract too many students from far away. This has been proved by calculation of its average distance from the origin of pupils to school, 1706 meters. Compared with the upper chart in this figure, the value is below 1, which answers for the fact that it does have a big capacity. Therefore, the other similar school whose values fall in the space between 4 and 14 should be removed some students or the school should be moved to near the demands.
Excess capacity of school (the current)

Figure 6-7 Excess capacity of school (the current)

Comparison of student number with capacity (the current)

Comparison of student number with demand (the current)

Figure 6-8 Comparisons between student number, capacity and demand
6.3. Analysis of the proposed pattern for the current situation

As described in section 5.5, in order to compare the results obviously, seven primary schools are closed and seven schools will be added. The attributes of the reserved fifty schools are not changed and together with three new schools, 57 schools make up the destinations of the proposed pattern for the current situation. The origins and road network are same with the current situation. Figure 6-9 displays the location of seven new schools in each street.

6.3.1. Coverage percentage

<table>
<thead>
<tr>
<th>No.</th>
<th>Area</th>
<th>Unserviced percentage (%)</th>
<th>Serviced population (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total Percentage</td>
<td>1 choice</td>
</tr>
<tr>
<td>1</td>
<td>Houjiatang</td>
<td>19</td>
<td>81</td>
</tr>
<tr>
<td>2</td>
<td>Zhuojiatang</td>
<td>22</td>
<td>78</td>
</tr>
<tr>
<td>3</td>
<td>Gaoqiao</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>Lituoxiang</td>
<td>64</td>
<td>36</td>
</tr>
<tr>
<td>5</td>
<td>Guitang</td>
<td>68</td>
<td>32</td>
</tr>
<tr>
<td>6</td>
<td>Yuhuating</td>
<td>29</td>
<td>71</td>
</tr>
<tr>
<td>7</td>
<td>Dongtang</td>
<td>39</td>
<td>61</td>
</tr>
<tr>
<td>8</td>
<td>Shazitang</td>
<td>3</td>
<td>97</td>
</tr>
<tr>
<td>9</td>
<td>Dongjingzhen</td>
<td>81</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>Yuhua district</td>
<td>34</td>
<td>66</td>
</tr>
</tbody>
</table>

Table 6-2 Coverage percentage in serviced/unserviced area (the proposed pattern)

All the percentage in the table means the served/unserved population to the total population in the street.

Table 6-2 clearly shows that the coverage percentage of the proposed pattern after making some modification on the current distribution. The improvement can be seen from the comparison of coverage percentage in Figure 6-10. It can be concluded that most of the unserviced percentage of the proposed pattern are less than the percentage of the current distribution. Accordingly, most of the serviced percentages of the proposed pattern are more than the percentage of the current distribution. But Shazitang Street is an exception for an excess coverage percentage in overlapped area results from a high-density school cluster. 68% people count for two to four schools. Figure 6-11 described the coverage percentage in overlapped area, all the percentages of the 1 choice increase while 2 two three choices decrease. Furthermore, the maximum count has dropped to three and no one counts to four choices. A more equitable distribution has achieved. The coverage percentages of the 2 to
4 choices decrease for the closure of schools in Houjiatang, Zhuojiatang and Shazitang Street. But the serviced percentage increases in two streets only drops slightly in Shazitang.

![Comparison of coverage percentage between the current and the proposed](image)

**Figure 6-10** Comparison of coverage percentage between the current and the proposed

![Comparison of coverage percentage between the current and the proposed in serviced area](image)

**Figure 6-11** Comparison of coverage percentage in serviced area

### 6.3.2. Comparison of demand and supply between the current and the proposed

Allocation of pupils to the nearest school in the new pattern is carried out, a comparison of EXCESS, defined as Formula 6-2, is shown in Figure 6-12, the red wave represents the value of new pattern and the blue one is the values of excess in the current distribution.
Comparison of EXCESS between the current and the proposed

![Excess Comparison Graph](image)

Figure 6-12 Excess capacity of school

Comparison of student/demand between the current and the proposed

![Student/Demand Comparison Graph](image)

Figure 6-13 Comparison between student number, capacity and demand
It is clearly that the red wave is changed more smoothly than the blue one, which indicates the gap between the demand and capacity is shorting. Especially around the seven new schools whose FID is from 1 to 7, if they are assigned a relative capacity according to their demand, then the capacity of each school equals to its demand and the excess capacity of each school falls to zero. The capacity of the seven new schools for recommendation is listed in Appendix 3. The improvement has been proved by the gap between capacity and demand in all school. The gap of the current distribution is 15222, for this proposed pattern, the gap reduces to 13758.

With the same comparison, the gap between the current student number, capacity and demand is described in Figure 6-13. Compared with the performance of the current distribution, the obvious change happens around seven new schools. The allocation of schools leads to part of the waves in both figures are on optimal state where the value equal to 1. Thus, the demand-supply relationship of the nearby school also changes correspondingly, towards the optimal line, but not so obvious as the new schools.

The above just is a recommendation to the government. When making a decision, how many schools can be added, seven or more in total and how long the suggested plan will be realized depend on the local government.

6.4. Analysis of the plan for primary school

In the analysis of the existing situation, the topographic map is a reference to rectify the residential data, because residential land in 2000 only covers the urban area and the agriculture settlements are neglected. But to the plan, it is impossible to generate the topographic map after 20 years. Due to a shortage of the plan of the residential land in rural area (see Appendix 4), there is a failure in disaggregation population to produce origins in the whole Yuhua district, so with a similar process with the previous section, the analysis of the primary school plan of the year 2020 is only focused on four adjoining streets, Houjiatang, Zhuojiatang, Dongtang and Shazitang. They are located in the northwest of Yuhua district (see Figure 6-14). The area of the four streets rang from 1.71 square kilometres to 4.80 square kilometres with population ranging from 67 thousand to 162 thousand.

In Figure 6-15, the red triangle represents the existing primary school and the green circle with a cross means the location of planned facilities. In these four streets, the number of the existing facilities is 20 while the plan is 18. After closing 7 schools another 5 new schools is added.
6.4.1. Coverage percentage

Appendix 6 describes the serviced area and unserviced area. Based on a calculation of the total population within in there, Table 6-3 summarizes the coverage percentage of the plan.

<table>
<thead>
<tr>
<th>No.</th>
<th>Street</th>
<th>Total Population (people)</th>
<th>Population density</th>
<th>Unserviced Percentage (%)</th>
<th>Serviced percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Houjiatang</td>
<td>84600</td>
<td>H</td>
<td>19</td>
<td>81</td>
</tr>
<tr>
<td>2</td>
<td>Zhuojiatang</td>
<td>162000</td>
<td>M</td>
<td>15</td>
<td>85</td>
</tr>
<tr>
<td>3</td>
<td>Dongtang</td>
<td>67000</td>
<td>L</td>
<td>30</td>
<td>68</td>
</tr>
<tr>
<td>4</td>
<td>Shazitang</td>
<td>91000</td>
<td>M</td>
<td>8</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>Summarize</td>
<td>404600</td>
<td>M</td>
<td>17</td>
<td>83</td>
</tr>
</tbody>
</table>

Table 6-3 Coverage percentage in serviced/unserviced area (plan)

- All the percentage in the table means the serviced/unserviced population to the total population in the street.
- Population density: H: >40000 people/square kilometre
  M: 30000-40000 people/square kilometre
  L: <30000 people/square kilometre
6.4.2. Analysis on the capacity

In the absence of information about all the demand points and under the assumption that the school aged children in these four streets must attend the school in these areas. After allocating pupils to the nearest school, the demand-supply relationship is clarified. In these four streets, two schools have oversupplied capacity as for their demand. Others still have a shortage of seats (see Appendix 8). The capacity of schools needs to be replanted. Shown in Appendix 10, in the plan, two schools in the south of these four streets have oversupplied capacity, represented by purple triangle. This cannot reflect the actual precisely for the assumption that the demands out of the four streets do not allocated. Specially, to School 13 (enclosed by a ellipse in maps), the total demand is 775 in the current while it reduces to 111 in the plan, which conflicts with the two reasons that the population is rising and there is not any new school around it. Inversely, The school in the northwest of it is closed. But as for the most schools in north, this conclusion may be more accurate because students must attend the nearest schools. So if the gap between capacity and demand in these schools is filled, the balance will be achieved.

From the distribution of serviced and unserviced areas, we can see many hexagons are still in unserviced area. Integrated with the above analysis on capacity, it can be seen that the plan is not perfect. It has can be improved by a proposed pattern.

6.5. Analysis of the proposed pattern for the plan

Similar with the analysis on the current distribution of primary school, three primary schools in the plan are closed for the distance to each other is within 500 meters. For the sake of easy comparison, three new schools are added based on contour measure. The total number of school is 18 before and after relocating schools. Thus, a new pattern generates, called the proposed pattern for the plan, using three new schools and fifteen reserved schools together as the destinations. The origins and road network are same as the plan. Figure 6-16 displays the location of closed and new schools. Except for Shazitang Street, there is a decrease of one school also have a new one in each street. Table 6-4 calculates the coverage percentage in serviced and unserviced area.

<table>
<thead>
<tr>
<th>N.o.</th>
<th>Street</th>
<th>Unserviced Percentage(%)</th>
<th>Serviced percentage(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total Percentage</td>
<td>1 choice</td>
</tr>
<tr>
<td>1</td>
<td>Houjiatang</td>
<td>19</td>
<td>81</td>
</tr>
<tr>
<td>2</td>
<td>Zhuojiatang</td>
<td>9</td>
<td>91</td>
</tr>
<tr>
<td>3</td>
<td>Dongtang</td>
<td>15</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>Shazitang</td>
<td>8</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>Summarize</td>
<td>12</td>
<td>88</td>
</tr>
</tbody>
</table>

Table 6-4 Coverage percentage in serviced/unserviced area (the proposed )

All the percentage in the table means the servied/unserviced population to the total population in the street.

Figure 6-16 Closed and new school
Based on the results of allocating pupils to the nearest school, the capacity of the new schools is assigned according to the demand for the school (listed in appendix 9). As for three new schools, the balance has achieved between the demand and the supply. Together with another two oversupplied schools in the plan, five schools are not short of capacity.

6.6. Comparison between the current, the plan and the proposed pattern

In order to make the result convictive, same as the comparison between the current situation and the proposed pattern for it, the comparison in this part is carried out in two aspects.

6.6.1. Comparison of coverage percentage

Appendix 5.6 and 7 portray the serviced and unserviced area in the current situation, in the plan and in the proposed pattern respectively. The remarkable change of the plan, compared with the current situation, is that the blue hexagons representing the unserved settlements are less, which means a higher coverage percentage in serviced area has been achieved. But compared with the proposed pattern, it can be seen that the blue hexagons are much more, so the proposed pattern has the highest coverage percentage.

The above just makes judgement from vision. The conclusion can be proved by Figure 6-17 which is a comparison of coverage percentage between three patterns. In general, the coverage percentage in serviced area is increasing while decreasing in unserviced area step by step from the current to the plan, then to the proposed pattern, except for Shazitang Street. It is verified that the proposed pattern has the highest performance in total coverage percentage.

The percentage for one choice is benefit while for more than two choices is cost. As far as the overlapped area is concerned (see Figure 6-18), generally speaking, the percentage for one choice in the current has been improved by the plan, which has been improved by the proposed pattern. The percentages for two or three choices (overlapped area) in the proposed pattern is the lowest. Shazitang Street is still the exception for a slight decrease of the serviced percentage in the plan. Because the overlapped percentage is 68% in the current, 31% in the plan and the proposed pattern, there is more than 30% reduced. Even if the relocation is done in Houjiatang Street, the performance of total coverage percentage does not change. But the percentage for two to three choices has discounted for a half.

In sum, as for the coverage percentage, the accessibility of the current situation is improved by the plan, which is improved by the proposed pattern. Compared with the current situation, a fact should be detected that the master plan of the year 2020 already arranged the residential land more convergent by planning residential quarter (see 2.2.3), which make all the demands concentrate to the smaller parcel (see Figure 6-15). So, it is easier to locate public facilities than the scattered settlements in the current situation.
Comparison of coverage percentage

![Graph showing comparison of coverage percentage between three patterns.](image)

Figure 6-17 Comparison of coverage percentage between three patterns

Comparison of coverage percentage in serviced area

![Graph showing comparison of coverage percentage in serviced area between three patterns.](image)

Figure 6-18 Comparison of coverage percentage in serviced area between three patterns

### 6.6.2. Comparison of capacity

Appendix 10 reflects the result of allocating pupils to schools in the current distribution, in the plan and in the proposed pattern. Figure 6-19 is the comparison of excess capacity of schools, which is useful to assign capacity of school before it is planned. The optimal state is the value equal to zero, which indicates the saturation between the demand and supply from schools. If the value above zero means a school has an oversupply. We can see from this figure that most of the schools are below zero and have a shortage capacity. As for their demand, three schools have excess capacity in the current. Furthermore, after assigning relative capacity according to the demand, three schools have a balanced...
capacity, together with two oversupplied schools in the plan, in all five schools in the proposed pattern, do not have a shortage of capacity (see Figure 6-19). It is impossible to generate the data on the exact student number of school in the plan and the proposed, the comparison between current student number, the capacity and demand in each school cannot be done.

Comparison of excess capacity of school

<table>
<thead>
<tr>
<th>Capacity-Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2500</td>
</tr>
<tr>
<td>-2000</td>
</tr>
<tr>
<td>-1500</td>
</tr>
<tr>
<td>-1000</td>
</tr>
<tr>
<td>-500</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>1500</td>
</tr>
<tr>
<td>2000</td>
</tr>
</tbody>
</table>

Figure 6-19 Comparison of excess capacity of school between three patterns

6.7. Conclusion

This chapter is mainly concerned with the interpretation of results. The examples above show how a planner may use GIS and accessibility to analyze spatial problems that is relevant to the task of providing good service to children attending public school. The analysis deals with four patterns: the current, the proposed pattern for the current situation, the plan and the proposed for the plan from two perspectives.

The results of this part may give reason for the local planner or decision makers to develop a strategy to improve the accessibility. For example, except for adding new schools, some areas having poor access may be provided of new routes or improve road conditions. Some areas having lower accessibility cannot fill new schools in short time can add new bus line.

It is a pity that the master plan did not cover the rural area, so the research cannot get enough demand points to evaluate the plan, which leads to the result of plan is not exact or cannot reflect the actual situation precisely. The comparison just focuses on part of study area in order to make the result more accurate. Providing the compressive data are available, a complete comparison of the accessibility between the current situation and the plan can be performed based on the method developed in this research.
7. Conclusions and Recommendations

7.1. Introduction

The general reason of this study is the demand of primary school of school-age children. Also local planning institution just finished the plan for primary school in 2020 by conventional planning method, which cannot give accurate information on the relationship between demands and supply also accessibility to primary school. In this point, a more detailed method is a useful tool to analyse the accessibility to primary schools.

Under these conditions, the main objective of the study is to develop a methodology to evaluate the accessibility of the current primary schools and the plan for the primary school in 2020. Moreover, it covers the analysis on spatial distribution and capacity. Other secondary objective of the study is to give suggestions to improve the accessibility.

The research is done to measure accessibility by contour measure because it is a suitable way to describe the presence. Furthermore, the available data is enough to this measure method. This study is carried out in Yuhua district, Changsha, China, which concerns 500 thousand and 57 public primary school in the current.

The study involves the analysis on four patterns: the current situation, the proposed pattern for it, the plan and the proposed pattern for plan, focuses on three components of accessibility: origin, transport and destination, from two perspectives: spatial distribution and capacity, in order to evaluate the accessibility.

This is the last chapter. The findings will discuss, also covers limitations of the research and requirements for improvement in the next research.

7.2. Main findings

This research provides a full analysis of the accessibility and covers proposed pattern. But to the analysis for plan, based on the limited data, the comparison result is not exact or cannot reflect the presence precisely. From this point of view, this research result cannot make a comprehensive comparison of accessibility. The comparison just focuses on part of study area in order to make the result more accurate. But the complicated comparison can be conducted if the data are available with the method developed in this research. The method summarized in this study is not a sophisticated technical procedure. It is appropriate to analyse the accessibility for other public facilities. The results also prove the developed method is an effective way to evaluate accessibility and to propose acceptable centre location and to suggest proper capacity of public facility.

According to the problems in study area, main findings of the research are summarized in two parts: analysis of spatial distribution and comparison of capacity and demands.
7.2.1. **Analysis of spatial distribution**

The equality of spatial distribution is mainly quantified by coverage percentage after identifying serviced and unserviced area. In the current situation, it shows high scores around city centre, and low scores can be observed in outskirt. Moreover, in the urban area, there are some settlements count for more than one school. Thus it can be said in general that rural areas have always been given a discriminatory treatment while in the urban area, there are better facilities. The different extent coverage percentage is graded, which is the base for closing and adding schools. In order to improve accessibility, a method integrated GIS and accessibility is developed to generate a proposed pattern. By comparing the coverage percentage and the capacity, it can be concluded that the proposed pattern has a higher accessibility than the current situation.

This conclusion can be verified by the performance of the proposed pattern for the plan of the year 2020. To the plan for primary school, in the absence of information about the complete demand points in Yuhua district, the comparison focuses on four streets. It can be seen that the coverage percentage also has been improved step by step from the current, to the plan and finally the proposed pattern has the greatest score.

7.2.2. **Analysis of capacity**

Capacity is another index accessibility to primary school. It is can be concluded that some pupils travel to school more than 500 meters. After allocating pupils to the nearest school, three groups of figures: the existing student number in school, the demand for school and the capacity of school can be compared to detect the current situation of primary school. Then we find out currently, 20 primary schools have an oversupply capacity compared with their demand. As for the new adding primary school, in order to achieve a balance between the supply and the demand, the capacities of theirs are assigned according to their demand. In the proposed pattern for the current, at least 27 schools are not short of capacity. In plan, 2 schools are short of seats under the assumption that all the school-age children attend schools in this area. In the proposed pattern for the plan, 3 new schools are assigned the balanced capacity, so in total, 5 schools are not short of capacity.

All in all, both from the spatial distribution and the capacity, the proposed pattern has achieved greatest performance in accessibility.

7.3. **Advantages of the method developed in this thesis**

The main purpose of this thesis is to describe and illustrate a method to support decisions on evaluation of accessibility using network analysis. The problem of mapping the balance between the number of pupils and the availability of primary school is described. It presents decision makers with a flexible tool. Based on different data, the evaluation can be implemented. The method used here offers several advantages.

- The accessibility analysis provides a detail description of the relationship between demand and destination, also including the transport. To the conventional method, only the destination is treated, which cannot place the facility to the location where it is most needed.
• It allows a better incorporation of the spatial element in more detail in the decision making process, such as unsafe aspects in the travel from settlement to school. If using time as impedance, then the class of roads also can be incorporated. The population data used in this research is detailed compared with the conventional method, which can also result in the precise evaluation result.

• One network can be used for different applications in (part of) the same area, because origin and destination locations are not part of the network anymore. For example, the simulations of improved situation.

The conventional method in public facility planning is also based upon distance. It can be concluded that the evaluation result with accessibility analysis is more detailed than the conventional method. But the conventional method has the advantage that it is not difficult to implement, so it is a simple tool in the foremost analysis.

7.4. Recommendations for further research

Since this study has explored the efficiency of the facility in providing access to school in study area, which can provide a base for the local planner or decision makers to develop a strategy to improve the accessibility. Due to lack of data and time constraints, this research has been carried out with some limitations, based on some assumptions.

• It did not incorporate private school and all the students are seen as the demand. Therefore it is not very likely to give an exact description of the behaviours of pupils. If the students’ address can be obtained, the result will be more accurate.

• The same method might be adapted and prove useful for analysis of other situations, where people compete for the use of facilities in the proximity of their homes. When defining catchment areas, competition is not taken into account, because in the overlapped area, the selection of the primary school is limited by Hukou. The further research is recommended to discard the Hukou limitation to propose a complete different perspective to the government.

• It is recommended to simulate the accessibility of different income group to primary school. In practice, the actual decision maker will not base his decision solely on geographical considerations. It only present the decision maker with a set of reference from which a choice can be made based on a simplified condition that all the customers of schools are from the same income group. The goals for a higher accessibility also should have incorporated the economics elements.
REFERENCE:


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Appendix 2 Comparison of capacity and demand of schools in existing distribution (Unit: people)

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Appendix 3 Capacity of the schools in proposed pattern for the current (Unit: people)
EVALUATION OF ACCESSIBILITY TO PRIMARY SCHOOLS

Appendix 4 Plan for primary school (2020)

Appendix 5 Serviced\unserviced area (current)

Appendix 6 Serviced\unserviced area (plan)

Appendix 7 Serviced\unserviced area (proposal)
### EVALUATION OF ACCESSIBILITY TO PRIMARY SCHOOLS

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**Appendix 8 Comparison between demands and capacity of plan**

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**Appendix 9 Capacity of the schools in proposed pattern for plan (Unit: people)**
Appendix 10 Allocation of students in the current, plan and proposed pattern