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AN ANALYSIS OF ACCESSIBILITY MEASURES FOR SCHOOL TRIP IN HONG KONG BY USING GEOGRAPHIC INFORMATION SYSTEMS (GIS)

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Abstract of thesis entitled 'An analysis of Accessibility Measures for school trip in Hong Kong by using Geographic Information Systems (GIS)' submitted by Ma Ming-lai for the degree of Master of Philosophy at The Hong Kong Polytechnic University in December 2000

Accessibility is an important element in analyzing the efficiency of a transportation system and in its planning process. Previous studies of accessibility had provided their distinctive methods of deriving various accessibility indices for the measurement of accessibility level. However, these were often limited by the lack of generality for applying in different situations and few of them conducted their studies by applying spatial information technology. With the advent of spatial information technology, a more detailed networking analysis covering the entire studying area is made possible. This paper aims at:

1. evaluating past accessibility indices by applying them empirically to selected regions of Hong Kong with the use of geographical information systems;
2. to infer an accessibility index that is more applicable in measuring the school trip in the case of Hong Kong.

Selected regions in Hong Kong are taken as examples to demonstrate the connectivity level within a local transport network system. Two regions with different stages of development are selected for this study, namely, Shatin and Tseung Kwan O. It focuses in studying the schooling trip of secondary school students from their living places (origin) to the secondary schools (destination) within the regions they live. This study is conducted in a regional scale in which only the intra-regional trip is taken into consideration.

The prerequisite of conducting the study is to select the suitable accessibility indices from the past studies for analysis. In order to facilitate the study, those indices are divided into two types, the gravity-type and the non-gravity type. Only those gravity-type indices are selected for further analysis. By using suitable database and GIS networking software, quantitative variables can be more accurately derived for testing and comparing the applicability of various accessibility indices.
Results show that the measures of Ingram and Clark are more applicable in measuring the school trip in the case of Hong Kong. This study provides an alternative method by applying the GIS method in transport study. It shows that it is a more efficient method in handling large amount of data, so a more comprehensive study can be conducted.
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CHAPTER 1
INTRODUCTION

1.1 Background

The transportation system in Hong Kong is mainly shaped by the Comprehensive Transport Study (CTS) in 1976 and the Second Comprehensive Transport Study (CTS2) in 1991. The CTS in 1976 provided the basic guidance to the development of the transportation system in Hong Kong. It provided some “transport models” or “indicators” in the transportation planning process. The CTS2 in 1991 was only a continuation of the CTS in 1976. The main contribution of the CTS2 was based on the indicators and the models provided in the CTS in 1976.

In the Comprehensive Transport Study in 1976, a series of transportation models were made for shaping the future transportation planning of Hong Kong. The accessibility model was selected and only studied in details in this study. The goal of the study of the CTS in 1976 was to maintain mobility for passengers and freight transport. Actually, the entire infrastructure constructed during this period was based on the objectives determined by this study. The First White Paper on Transport Policy\(^1\) contained three principles: 1) improvement of the road system; 2) expansion and improvement of public transport; and 3) more economic use of the road system (Transport Department et al., 1976).

The Second Comprehensive Transport Study in 1991 was the extension of the first one. It was a revision of the previous study with a further development from it. The goal of this study was to develop a detailed highway and railway infrastructure investment program to get the best value for money from the funds available (Wang & Yeh, 1993). Similar to the Comprehensive Transport Study in 1976, it contains three principles in the Second

\(^1\) The First White Paper on Transport Policy, which was produced in 1979, was based on the First Comprehensive Transport Study in 1976. "This White Paper set out what the Government proposed to do to maintain Hong Kong’s mobility for the period up to 1991." (Wang & Yeh, 1993).
White Paper on Transport Policy\textsuperscript{2}, namely; 1) improving the transport infrastructure; 2) improving public transport; and 3) managing the demand for road use (Transport Department et al., 1991).

From these two transport studies we get the insight that both studies give priority to public transport development. They encourage the development and the use of public transport instead of the private transits to the general public. When referring to the goals of CTS1 and CTS2 as mentioned above, it can be said that CTS in 1976 is a demand-based policy while CTS2 is a resource-based policy. Demand-based is in the sense that the target of the policy is to pinpoint the mobility for passengers. On the other hand, resource-based policy is in the aspect of how to distribute the limited amount of resource for a good use.

‘Accessibility index’ was one of the concepts introduced in CTS1. It indicates how easily residents move from one place to another under the already established transportation system. In this sense, accessibility indices can help reflect the existing transportation systems through residents’ daily travel behavior. It can be working, schooling and shopping trips etc.

1.2 Objectives

Accessibility is a complicated and a broad concept. It can be applied in various fields of study. It can be a factor for the determination of urban rents, densities and land uses (Dalvi & Martin, 1976, pp17; Hansen, 1959). It can also be an indicator to reflect the travel demand for trips. In this study, the concept of accessibility is confined to the realms of transportation only. It emphasizes on the nature of trips generated from one origin to another destination. There is nothing related to allocation model.

\textsuperscript{2} The Second White Paper on Transport Policy was based on the Second Comprehensive Transport Study in 1991.
Accessibility in transportation is generally understood as “the ease of reaching” (Jones, 1981). The attractiveness of a region is heavily dependent on how good the network system of that region is and the linkages of that region to the rest of the territory. So, it becomes the agenda in any new town planning project in providing a well-facilitated transportation network linking the internal region to the rest of the territory.

With these in mind, the objectives of this study are

1. to evaluate past accessibility indices by applying them empirically to selected regions of Hong Kong with the use of geographical information system;
2. to infer an accessibility index that is more applicable in measuring the school trip in the case of Hong Kong.

In other words, the data collected is for the purpose of conducting an empirical study of accessibility for school trip.

1.3 Significance

The objective of this study is to find out a more appropriate accessibility index for school trips in a confined region in Hong Kong’s case by using GIS method. Accessibility is an important topic in transportation geography. It also plays an important role in transportation planning system process. For the past study of accessibility indices, it is rare to evaluate these indices by using GIS method. So, the significance of this study is to evaluate the accessibility indices for the case of Hong Kong by using GIS method. The result of this study can be a reference for the transport planning of Hong Kong.

Through this study, evaluation of the existing transport facilities and the validity of the components of the accessibility indices are also reviewed. This helps strengthen the understanding of the relative importance of each individual component for influencing the value of the accessibility index and the rationale for the inclusion of such factor. Actually, in studying the topic of accessibility in transportation, the factors included in
the index are important. They can reflect the main theme of that index. Some may put the emphasis on one or two particular factors, while some may be in a more even manner. As a result, two indices measuring the same region may have a great difference among themselves because their emphases are different. So, the evaluation of the composition of the accessibility indices not only can help understand the relative importance of each individual factor, but also the implicit meaning of the index itself.

The results of this study can be a reference in transportation planning for the distributions and allocations of transport facilities to the population of a confined region in Hong Kong. The consideration of individual travel pattern confirms one of the goals of transportation planning.

1.4 Methodology

This section gives a brief introduction of how the study is carried out. The nature of trip, studying areas, software used and the selected accessibility indices are reviewed.

The nature of trips can be classified in terms of the trip purposes in transportation planning. Some common trip types include work trips, shopping trips, social or recreation trips, business trips and school trips. Among these trips, school trip is selected for this study. School trip is a more appropriate choice in a small-scale study because this type of trip is more predictable. According to the "school web" policy of the local education system, a greater proportion of secondary school students should study in the same district they live. The origin is defined as each residential site while the destination is defined as each individual secondary school within the same district.

Two regions (new towns) Shatin and Tseung Kwan O New Towns are selected to study the accessibility of school trip for secondary school students. These two new towns are chosen because they can represent two areas, with different history of development, very
different accessibility levels in terms of their transportation networks connected internally
and externally.

The choice of Shatin as one of the study regions is that it is a typical new town with a
longer history and better developed transport network for both internal and external
linkages. On the other hand, Tseung Kwan O is a newly developed new town. Thus, both
the internal and external transport networks in this region is relatively less developed
when compared with those in Shatin.

To facilitate complicated calculations process of network analysis and handle a large
amount of data more efficiently, the GIS technology is used in analyzing the accessibility
models in this study. “Geographical Information System (GIS) is the most suitable
technology for storing, analyzing and displaying transport information. It can integrate
maps with databases, digital drawings, photographs and so on for visual display and
analysis. It will facilitate dissemination of transport information to the public via
established distribution channels such as variable message panels and electronic mass
media” (HKSAR, 1999).

The software used in this study is ArcView GIS and the ArcView Network Analyst. The
ArcView Network Analyst can help find out the shortest path in terms of travel distance
(meter) and travel time (minutes). These data are useful in the analyzing process and
would be put in the database of Visual FoxPro for calculation.

The results of accessibility indices are compared with the hypothesis that Shatin is more
accessible than Tseung Kwan O to a large extent. The hypothesis will be tested
empirically by real world data.
1.5 Summary

This chapter has reviewed the background of the transportation development of Hong Kong which is mainly shaped by the CTS1 and CTS2. The objectives, the significance and the methodology of this study are outlined. Detailed discussion of the process in conducting this study will be presented in the coming chapters.

In chapter 2, there will be a literature review of the previous studies of accessibility and the accessibility indices involved. The accessibility indices are classified in accordance with the underlying concept of these accessibility models. They are divided into the Gravity type and Non-gravity type. In addition, an evaluation of the strengths and limitations of those accessibility indices are mentioned. In chapter 3, the literature review on the studies of transportation system in Hong Kong and foreign countries is discussed. Factor derivation and empirical testing are carried out in chapter 4. There is a detailed discussion on the method in deriving some of the factors in the accessibility indices. The factors are travel cost and the calibration parameter. After deriving all the required factors for the database, empirical testing against these indices is carried out. The results of the testing are presented in chapter 5. This chapter includes the presentation of the results generated from each index and the analysis of the results. A summary and an evaluation of the results are made. Finally, conclusion and recommendations for this study are in chapter 6.
CHAPTER 2
LITERATURE REVIEW

2.1 Definitions

Many researches over the issue on accessibility have been conducted and the term has been defined in the way related to various fields of study.

Accessibility is a term that is usually applied in the field related to transport and land use planning.
The Pitman Dictionary (1974) defines this term as “the state or quality of being approachable”:

*Accessibility is normally defined as follows:*
Accessibility is generally understood approximately as ‘ease of reaching’ (Jones, 1981).
“Accessibility is an abstract concept which describes where activities are located in relation to dwellings and how convenient or difficult it is to get to these activities” (Black & Conroy, 1977).

“Accessibility means capable of being reached, thus, implying a measure of the proximity between two points”. “Alternatively, accessibility is related to the ability of a transportation system to provide a low cost and/ or quick method of overcoming the distance between different locations.” It can also approximately be defined as “the inherent characteristic (or advantage) of a place with respect to overcoming some form of spatially operating source of friction (for example, time and/ or distance)” (Ingram, 1971).

“Accessibility has generally been defined as some measure of spatial separation of human activities. Because transportation systems connect spatially separated activities, accessibility is of interest in planning for transport systems.” (Sherman, Barber & Kondo, 1974).
According to what Gould states: "Accessibility...is a slippery notion...one of those common terms that everyone uses until faced with the problem of defining and measuring it" (Gould, 1969, p. 64). So, accessibility is usually defined in the way related to the work concerned.

Some studies have been concerned solely with the spatial separation of a point from another, or from all other points:

"the accessibility of a point in a system is a function of its location in space with respect to all other points in the system" (Hack, 1976).

"... accessibility is a measurement of the spatial distribution of activities about a point, adjusted for the ability and the desire of people or firms to overcome spatial separation" (Hansen, 1959).

Some have defined accessibility in terms of the travel cost of observed or expected trips.

"... accessibility will, however, be improved by a road system which minimizes the distance-time of journeys" (Stone, 1973, p.252).

"accessibility........will imply relative nearness either in the sense of a direct linkage or a minimum expenditure of travel cost or time" (Muraco, 1972).

Some studies have been concerned with the opportunity which an individual or type of person at a given location possesses to take part in a particular activity or set of activities.

"Accessibility can be defined in terms of the opportunity to use facilities after journeys of various lengths. It thus depends on the size and form of the settlement and will usually increase the greater the density of development and the more compact the settlement shape" (Doling, 1979).

Some consider population characteristics which influence the travel pattern.

A few studies have identified accessibility with the consumer surplus, or net benefit, that people achieve from using the transport and land-use system (Williams, 1976 & Leonardi,
When referring to the review above, there is a common phenomenon that most of the studies of accessibility carried out in a very early stage. Actually, these studies are the fundamental elements of accessibility studies. They are the bases for further development on this topic. For example, for the study of Linneker & Spence (1992), its study was to compare the past accessibility indices through the empirical test by using the case study of the impact of the M25 London Orbital Motorway on Britain. Its aim was to evaluate the difference between the market-potential and access-cost measures of accessibility based on the existing accessibility indices. Also, for the study of space-time and integral measures of individual accessibility by Kwan (1998), eighteen gravity-type and cumulative-opportunity accessibility measures are examined by using a point-based spatial framework. For the study of Handy (1997), it was to justify the concept of accessibility between the academic literature and the practical application. Obviously, the studies mentioned above are developed based on the past studies of accessibility indices. Such phenomenon implies that the early studies of accessibility form the foundation for further research made in this topic.

The definitions of accessibility above can only represent one or two main themes. Some define accessibility in the light of overcoming spatial separation, some emphasize the travel cost, opportunity or attractiveness of the destination whereas some emphasize the consumer surplus. The previous researchers defined the term accessibility above are in the light of the objectives of their studies. With this in mind, the definition of accessibility adopted in this study is defined in the way more relevant to the theme of this study instead of choosing one or two from those above. Hence, the definition of accessibility is defined as follows:

Accessibility of this study is to analyze the ease of movement from one place to another based on the existing transportation system. The study aims at evaluating the existing transportation system and assessing the extent of spatial separation (hindrance/obstacle imposed by the existing transportation system). It is hoped that in the end measures are
recommended to improve the connectivity or linkages of the existing transportation networks.

This definition is the combination of the concepts of the definitions above and represents the main theme of this study. The details of how to analyze the transportation networks would be examined in the later chapters of this study.

2.2 Previous Studies of Accessibility Measures

Accessibility indices can be divided into gravity type and non-gravity type. The accessibility models based on the concepts of attractiveness and interaction between two places are categorized as gravity type accessibility model. They are the accessibility measures of Hansen, Ingram, K. M. Martin & M. Q. Dalvi, Clark, Weighted mean travel costs of the study of Javier Gutierrez, Gabriel Gomez and the First Comprehensive Transport Study. These models require spatial analysis. The remaining measures of accessibility are grouped as non-gravity type. Non-gravity type accessibility indices do not carry the meaning of spatial interaction between two activity places. The term ‘spatial interaction’ can be interpreted by distance cost or time cost between two places quantitatively. Distance cost or time cost implies that activities take place between two regions. So, distance cost or time cost cannot be found in the non-gravity type accessibility indices.

Actually, gravity type models are based on the concept of Basic Gravity Model. The Basic Gravity Model is about the concept of spatial interaction between two attractive bases. In this aspect, there is a need to have a review of the concept of the Basic Gravity Model.
The Basic Gravity Model

It's a theory to describe how the attractiveness of two factors in two places influencing the flow and attractiveness of the two regions (Taaffe et al., 1996). It is a theory in analyzing the concept of spatial interaction in which the interactions between the two activity bases are considered. The two variables used in this theory are population and distance.

\[ I_{ij} = f(I_{ij}) = f \left( \frac{P_i P_j}{d_{ij}} \right) \]  \hspace{1cm} (2.1)

\( I_{ij} \) = Interaction between i and j
\( P_i \) = Population in zone i
\( P_j \) = Population in zone j
\( d_{ij} \) = distance between i and j

2.2.1 Gravity Type Accessibility Measures

Hansen(1959) had studied how land use was influenced by the factor of accessibility. In his paper, he tried to define the term accessibility as the potential of opportunities for interaction. He stated that this definition was different from the usual one in that "it is a measure of the intensity of the possibility of interaction rather than just a measure of the ease of interaction." In this sense, the "population-over-distance relationship" or "population potential" is obvious. According to what he interpreted, accessibility is a spatially continuous measurement, so it can be mapped in the way similar to heights depicted on topographic maps. He formulated the concept of accessibility in the following formula:
\[ A_2 = \frac{S_2}{T_{1-2}^x} \]  

where

\( A_2 \) is a relative measure of the accessibility at Zone 1 to an activity located within Zone 2;

\( S_2 \) equals the size of the activity in Zone 2; i.e., number of jobs, people, etc.;

\( T_{1-2} \) equals the travel time or distance between Zones 1 and 2;

\( x \) is an exponent describing the effect of the travel time between the zones.

In addition to the above formula, he extended the concept to include the case when more than two zones were involved. The formula then became:

\[ A_i = \frac{S_2}{T_{1-2}^x} + \frac{S_2}{T_{1-3}^x} + \frac{S_2}{T_{1-n}^x} \]

It is the summation of the accessibility of individual zone. In more general form, it can be expressed as:

\[ A_i = \sum_{j=1}^{n} \frac{S_j}{T_{i-j}^x} \]  

(2.3)

As it is very controversial over the question of what the function of distance should be, the exponential function is generally used. He suggested that the exponent should be unity and believed that the value of the exponent in this accessibility or potential model must be the same as that used in the gravity model. An empirical test of gravity model reviewed that the exponent value ranged from 0.5 to almost 3.0. A conclusion from this empirical test was that the trip became more important when the exponent value declined. The decrease of the exponent value implies that the factor of distance becomes a less
restrictive factor. Besides, he generated some factors that should also be considered in computing the accessibility, namely terminal time and travel time.

Ingram (1971) emphasized the operational form of accessibility. He further refined the term accessibility into Relative Accessibility and Integral Accessibility. The former referred to the degree to which two places (or points) on the same surface is connected. The two points to each other may not be equal in intensity, so called the asymmetric nature of accessibility. The latter referred to a given point as the degree of interconnection with all other points on the same surface. It is an operational form in which it is derived from a set of relative accessibility for a point. Thus, the formula is:

\[
A_i = \sum_{j=1}^{n} a_{ij}
\]  

where \(A_i\) is the integral accessibility at the \(i\)th point and \(a_{ij}\) is the relative accessibility of point \(j\) at \(i\).

It is the summation of each individual relative accessibility between points \(i\) and \(j\).

He then used different measurement methods to study the Hamilton urban area, Ontario. Many traffic studies reviewed that the relationships between travel time, travel cost and traveled distance are significant. Initially, in order to simplify the study, he used the straight line distance. He stated that in the case of a straight line distance between two points, the integral accessibility of the \(i\)th point was defined as the average of the relative accessibility at that point:

\[
A_i = \frac{1}{n} \sum_{j=1}^{n} d_{ij}
\]  

where, \(d_{ij}\) is the straight line distance between points \(i\) and \(j\).

As it takes the average of the distance between points \(i\) and \(j\), the smaller value of \(A_i\)
implies higher integral accessibility.

Then an isoplethic map was constructed. The results indicated that the point of highest integral accessibility was not located at, or near, the central business district (the centre of the Hamilton CBD corresponds approximately to the intersection of King & James Streets); rather it was situated about 1 \( \frac{3}{4} \) miles to the east.

The last move was to apply in the case of rectangular distance. It is because Hamilton City contained more rectangular pattern like street. To be more realistic, the barrier (the mountain in Hamilton City) should also be considered.

As mentioned, integral accessibility defined by Ingram was derived from individual accessibility. The measurement methods of relative accessibility are crucial. According to Ingram, there are three types of measures of relative accessibility, namely, reciprocal function, negative exponential function and normal function. The reciprocal function is the most common function utilized in interaction and gravity models to manipulate distance. When it links to relative accessibility, it is in the form of:

\[
a_{ij} = 100 \, d_{ij}^{-k}
\]  

(2.6)

where, \( a_{ij} \) is the relative accessibility, \( d_{ij} \) is the distance between points \( i \) and \( j \) &. \( -k \) is the parameter. According to the interpretation of Ingram, the alteration of the value of \( k \) alters the rate of descent and the position of the inflection point. The study of the variation in \( k \) for various modes of travel and trip lengths can provide useful descriptive information. The equation reflects that there is a negative relationship between relative accessibility and distance.

Negative exponential function is in the form of:

\[
a_{ij} = 100 \, e_{ij}^{-d}
\]  

(2.7)
where $e$ is the exponential (but is not defined clearly).

This equation also shows the negative relationship between relative accessibility and distance. When compared with the reciprocal curve, it declines relatively slower, implying that it places more emphasis on accessibility over short distances.

Normal function is in the form of

$$a_{ij} = 100 e^{-(d_{ij}/v^{-1})}$$  \hspace{1cm} (2.8)

where, $v$ is a constant determined for a given system of points;

The function equals to 100 at the origin. According to Ingram, it has a slow rate of decline in the region close to the origin, resulting in a zone where the frictional effect of distance on accessibility is low.

Knudsen and Kanafani (1974) had a research on the definition and measurement of accessibility in urban areas. Initially, the postulation of this study is that “accessibility should be defined as a measure of the ease of travel between points of origin and points of destinations”. It does not include any personal preferences in travel behavior (travel preference).

This study also revealed some mathematical measures of accessibility, Clark’s measure is one of them. According to Clark (1971), the accessibility level is measured by the following formula:

$$A_i = \sum_j f(c_{ij}) O_j$$  \hspace{1cm} (2.9)

where $f(c_{ij}) = t_{ij}^{-1}$

$t_{ij} =$ travel time between origin $(i)$ and destination $(j)$

$O_j =$ number of employment opportunities at the place of destination $(j)$
The equation hence can be rewritten as:

$$A_i = \sum_j O_j / t_{ij}$$  \hspace{1cm} (2.10)

"$A$" in this sense, is demonstrated as the number of "work places" or "employment opportunities per time unit".

The output is displayed by means of an isoline map. The points lying on the same line have the same accessibility value.

Besides, the equation also takes the factor of various modes into consideration.

$$a_{ij}^{(m)} = f(c_{ij}^{(m)})$$  \hspace{1cm} (2.11)

where,

$a_{ij}^{(m)}$ = accessibility from \((i)\) to \((j)\) by mode \((m)\)

$c_{ij}^{(m)}$ = travel cost from \((i)\) to \((j)\) by mode \((m)\)

$f(c)$ = accessibility-function or (cost function)

This equation indicates the relationship between accessibility and travel cost from its origin to its destination. The factors like transportation system, location of origin and location of destination tend to influence the cost between origin and destination for each mode.

Martin and Dalvi (1976) had a research on the concept of accessibility in comparing the private and public transport in London. The data used was from the London Transportation Study (1962). The formula used in this study was the modification of Hansen's measure:
\[ A_i^k = \frac{\sum_{j=1}^{a} w_j \exp(-\beta c_{ij}^k)}{\sum_{j=1}^{a} w_j} \]  

(2.12)

where

- \( A_i^k \) = accessibility afforded by mode \( k \) to household residents in zone \( i \)
- \( W_j \) = measure of attractiveness of zone \( j \)
- \( c_{ij}^k \) = cost of travel from zone \( i \) to zone \( j \) by mode \( k \)
- \( \beta \) = derived from the distribution functions used in the LTS trip distribution model.

The main theme of this paper is to analyze the public transport accessibility patterns in inner London. A comparison between private and public transport accessibility pattern has also been made. Four measures of areal attractiveness (\( W_j \)) have been used in this study, namely, total employment, retail employment (convenience goods), retail employment (durable goods), and population. It plays an important role in determining the public transport accessibility pattern. The travel cost (\( c_{ij} \)) from zone \( i \) to zone \( j \) is measured in terms of travel time. The results showed that the corresponding coefficient correlation is more significant when the accessibility is based on employment and less on population.

**The Comprehensive Transport Study.** It's the first comprehensive transportation planning of the network systems layout in Hong Kong (Transport Department et al., 1976). The accessibility indices used in CTS were mainly related to the movements to job opportunities by using public transit during peak hours. It was assumed that no private transit was to be used in such measurement. It took into account of the average travel time of the residents by using public transport in reaching the nearest 600,000 job opportunities for each zone. The concept of accessibility is expressed as the following formula.
\[ Ai = \left[ \frac{1}{M} \sum_{j=1}^{k} E_j T_{i,j} \right]^{x} \]  

(2.13)

where

\( Ai \) = Average travel time to reach the nearest M activities from Zone i.

\( E_j \) = Job opportunities in Zone j.

\( T_{i,j} \) = Travel time by public transport between Zone i and Zone j.

\( M = \sum_{j=1}^{k} E_j \)

\( x \) = Travel time exponent

\( k \) = The farthest zone from i whose job opportunities, E, (either all or part of them) belong to the set of nearest M activities from Zone i.

A range of accessibility level is classified to indicate different levels of accessibility:

<table>
<thead>
<tr>
<th>Accessibility Level</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High Accessibility</td>
<td>0-24</td>
</tr>
<tr>
<td>High Accessibility</td>
<td>25-36</td>
</tr>
<tr>
<td>Medium Accessibility</td>
<td>37-48</td>
</tr>
<tr>
<td>Low Accessibility</td>
<td>49-60</td>
</tr>
<tr>
<td>Very Low Accessibility</td>
<td>61 and over</td>
</tr>
</tbody>
</table>

Gutierrez & Gomez (1999) have conducted a research on the impact of orbital motorways on intra-metropolitan accessibility by using the case of Madrid's M-40 Highway. It is the study of the metropolitan orbital motorways in investigating the impact of the construction of M-40 motorways on the accessibility level to the whole transportation system. This paper pointed out that accessibility has its social and economic implications. The higher the accessibility level, the higher quality of life and in return the increasing attraction of economic development. The term accessibility was defined as "the ease with which activities may be reached from a given location using a particular transportation system" (Morris et al., 1978). It was therefore suggested that the accessibility study should consider the types of transport system and the types of distance.
variables to be used. Three indicators in measuring accessibility used in this study were the Weighted Mean Travel Costs, Opportunity Accessibility (potential destinations within a certain transport cost limit) and Economic Potential.

**Weighted Mean Travel Costs:**
It is an indicator, which consists of calculating the weighted mean travel cost (time) between each node and all centroids. The formula is as follows:

\[
A_i = \frac{\sum_{j=1}^{n} (T_{ij}X_M_j)}{\sum_{j=1}^{n} M_j}
\]  

(2.14)

where,

\(A_i\) = the accessibility of node \(i\)

\(T_{ij}\) = the travel time through the network the node \(i\) and centroid \(j\) (in minutes)

\(M_j\) = the mass (employment or population) of the destined centroid

This formula is purely a measure of the travel times between different places. The indicator reviews the differences of the travel time before and after constructing the M-40 motorway.

**Opportunity accessibility (potential destinations within a certain transport cost limit):**
It is stated that “The accessibility of a node in a network is measured as the population or economic activity within a certain transport cost limit” (Gutierrez & Gomez, 1999). The indicator in this study is used both in the regional scale (Lutter et al., 1992) and in the metropolitan one (Helling, 1996) but it does not include any formula in measuring the accessibility level.
Economic potential:

It is pointed out that the typical indicator of measuring accessibility is the gravity-type measure. The emphasis of such measure is stated as “the degree of opportunity between two areas is positively related to the sizes of the attractive masses of the zones and negatively related to the impedance between the zones” (Linneker and Spence, 1992). The typical formula is as follows:

$$P_i = \sum_{j=1}^{n} \frac{M_j}{C_{ij}}$$

(2.15)

where,

$P_i$ = the economic potential of node $i$

$M_j$ = the measure of the economic activity of the centroid $j$

$C_{ij}$ = a measure of the transport costs between $i$ and $j$

$a$ = a parameter reflecting the rate of increase of the friction of distance

Having chosen three indicators used in this study, ARC/INFO, a Geographic Information System package is used in the analyzing process. The average speed, the length of each arc and the travel time were also taken into account. The results showed that with the improvement of the transportation network, i.e. after the construction of the new orbital motorway M-40, the accessibility level has been improved.

2.2.2 Non-gravity type Accessibility Measures

The Shimbel Measure: this measure aims at avoiding the choice problem by covering all the possible destinations for each node (Shimbel, 1953). It is an aggregate index and in the form of
\[ S_i = \sum_j d_{ij} \]  \hspace{1cm} (2.16)

where \( d_{ij} \) represents the distance between \( i \) and \( j \).

When making comparison between points on different networks, the average accessibility to all relevant points could be used:

\[ A_i = \frac{1}{n} \sum_{j=1}^{n} d_{ij} \]  \hspace{1cm} (2.17)

Tomazinis (1961) had modified the accessibility equation in which it included three types of accessibility. It is shown as follows:

\[ A_i = \sum_{j=1}^{n} (A_s + A_c + A_e) \]  \hspace{1cm} (2.18)

where

\( A_i \) = Total accessibility of zone \( i \)
\( A_s \) = Social accessibility
\( A_c \) = Commercial accessibility
\( A_e \) = Employment accessibility

This measure of accessibility was the combination of social, commercial and employment accessibility. Tomazinis modified Hansen's measure by adding these three factors in the accessibility measuring methods.

Schneider (1963) had developed another set of accessibility measurement method for the Chicago Area Transportation Study. The interaction between land use and the transportation system was emphasized. Originated from the concept of intervening
opportunities, it was assumed that a trip from the zone of origin would probably go beyond a particular zone of destination. The formula is as follows:

\[ R_{ij} = e^{-uw_{ij}} \quad (2.19) \]

where

- \( R_{ij} \) = The probability that a trip originating in zone \( i \) will travel farther than zone \( j \)
- \( V_{ui} \) = The cumulative number of trips or opportunities between zone \( i \) and zone \( j \)
- \( u \) = The parameter of unwillingness to travel
- \( e \) = The base of natural logarithm (2.7183)

### 2.3 Comments

Some common limitations can be found in the previous studies of accessibility indices. Generally speaking, these studies only show the methods and the final results without displaying the working process. Besides, there is a lack of detailed explanation of the independent factors used in the accessibility indices. For example, there was no detailed explanation for the terms “distance”, “travel time” and “size of activity base” and the derivation of “parameter”. So, the measurement methods of these independent factors were not clearly indicated. Also, some special terms used in the previous studies such as “zone”, “node”, “point” and “centroid” were not defined and explained clearly. Apart from the First Comprehensive Transport Study in 1976, all other previous studies described did not provide any indicator to reflect the accessibility level of the region. That is, it cannot be concluded with reference to a standard to determine whether a place is accessible or not. As different combinations of different independent factors would reflect the complexity of real world situation, a thorough understanding of the methods in deriving these factors is necessary.
The main concepts of the previous studies of accessibility indices is summarized in Table 2.1.

Table 2.1 Factors of various Accessibility Indices.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Types</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Distance cost</td>
</tr>
<tr>
<td>Clarks (1971)</td>
<td>Gravity</td>
<td>✓</td>
</tr>
<tr>
<td>Ingram D. R. (1971)</td>
<td>Gravity</td>
<td>✓</td>
</tr>
<tr>
<td>Javier Gutierrez &amp; Gabriel Gomez (1999)</td>
<td>Gravity</td>
<td>✓</td>
</tr>
<tr>
<td>The Comprehensive Transport Study (1976)</td>
<td>Gravity</td>
<td>✓</td>
</tr>
<tr>
<td>Walter G. Hansen (1959)</td>
<td>Gravity</td>
<td>✓</td>
</tr>
<tr>
<td>Schneider (1963)</td>
<td>Non-gravity</td>
<td>✓</td>
</tr>
<tr>
<td>The Shimbel Measures (1953)</td>
<td>Non-gravity</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 2.1 clearly shows the categories the various accessibility indices belong to and the factors included. As mentioned in section 2.2, only the gravity type accessibility indices include the factor of distance or time cost in representing the concept of spatial interaction between two activity places. So, with the exception of Shimbel's measure, only the gravity type accessibility indices include the factor of time or distance cost. The exclusion of Shimbel's measure from gravity-type accessibility indices because this measure only shows the connection between one place to another. There is no interaction between two activity bases.
2.4 Summary

This chapter has introduced various studies of accessibility measures. It includes the definitions and the previous studies of accessibility measures. Past studies of accessibility measures can be divided into gravity type and non-gravity type. Only the gravity type accessibility measures are selected for this study. Comments are made for the indices as a whole. A table summarizes the main concepts of accessibility measures in the last part.

The literature review of the use of GIS methods in transportation study will be discussed in chapter 3.
CHAPTER 3
TRANSPORT STUDIES IN GIS

This is the study of accessibility indices of transportation by using the Geographic Information Systems. Having reviewed the past studies on the concept of accessibility and various accessibility indices in chapter 2, there is a review on transport studies in this chapter. Before going in depth for the review of the past studies on transportation, an introduction of GIS method is made because this study is conducted by this method.

3.1 What is a GIS?

“A GIS is a computer-based system that provides the following four sets of capabilities to handle geo-referenced data: 1. input; 2. data management (data storage and retrieval); 3. manipulation and analysis; and 4. output” (Aronoff, 1991). The spatial and attribute data are stored in a database, so that both can be updated, retrieved and accessed easily. GIS technology is an ideal tool in handling the data which is geographically related.

One of the advantages of using GIS technology is that it is an ideal tool in handling data model. According to Choi and Luk (1992), an extended object-oriented data model for GIS applications can facilitate data modeling at two levels: geographic and geometric. The data model of geographic level deals with actual physical features such as countries, zones, and roads, while, at the geometric level, it deals with the spatial representations of the geographic counterparts.
3.2 GIS In Network Analysis

The use of a GIS in network analysis can efficiently trace the cost required for a trip generated. A GIS technology is a powerful tool for data capturing, storage, manipulation, queries, analysis and visualization. In other words, GIS technology brings to the user the ability to integrate, store, process, and output geographic information (Gunes et al., 2000).

The GIS technology is useful for the integration of different types of information which are in form of different layers. Analysis is made upon the layer after combining these different layers into one. The underlying concept for the use of GIS in this study is illustrated in Figure 3.1.

Figure 3.1 Underlying concept of the usage of GIS method for this study.

As illustrated in Figure 3.1, the usage of GIS technology in this study for network analysis is to integrate different layers into one. The required layers for this study include buildings, centerlines, base map, origin and destination. As a result, the final layer for analysis is the combination of these layers. The GIS package used in this study is ArcView 3.1 with the Network Analyst extension. The ArcView 3.1 forms the base
for the integration of variety types of data, while the selection of the extension of Network Analyst is for the analysis of networking. Detailed discussion on the usage of GIS for this study is in chapter 4.

3.3 Previous studies on transportation

In the following section, some previous studies on transportation are reviewed. They can be divided into two categories; one is the study within the perspective of Hong Kong while another is the foreign study.

3.3.1 Foreign studies on transportation

The study of Southworth et al. (1997)

This is the study on intermodal freight networks within a GIS platform. It is the study on designing a GIS database for intermodal freight routing. In this paper, the definition of intermodalism is in a broader sense. It does not simply imply containerized movements. Instead "freight is taken to involve intermodal transportation if it requires any kind of end-on transfer of goods between two different primary modes of transport on its journey from source to market" (Southworth et al., 1997).

In the analysis of intermodal freight networks, it involves the flow from source-to-market shipment. In a simple case like a single source-to-market shipment, the effort made in analysis may not be so great. However, with the growing complexity
of the economic system, it is more common to involve in multiple source-to-market shipment. As a result, creating a GIS database for intermodal freight routing can make the process of routes selection, traffic assignment for repeated source-to-market flows become cost efficient.

In creating a GIS database, a bi-modal transfer links are derived which contains the geographic location of the transfer activities and the attribute data for routing studies. Traffic locations of origins and destinations are denoted as point features, they are termed as centroids in that study. “Centroids can be linked to any modal network via one or more real or notional access connectors, by attaching such connections to spatially adjacent network links or, more commonly, network nodes” (Southworth et al., 1997). Actually, the above are only the algorithms for the creation of database. Two additional concerns also require paying attention for this study. One is on the dynamic nature on the enterprises, while another is the suitability of the data sources.

To sum up, this study has introduced the use of GIS method which is a more cost efficient way in network analysis. The term network analysis is not restricted to the study of immediate network systems such as road networks. Instead, the GIS method can also be applied in intermodal freight networks. As the authors suggested, such method can be applied in air transport also. “In studying the market conditions within any modal industry a GIS can be a very useful tool, mapping and highlighting the different routing structures and geographic sub-networks covered by different carriers, as well as (data permitting) those routes where high-speed, high-cost service options are available” (Southworth et al., 1997). So, a GIS is a tool that can be universally applied in many different cases.
The study of Hong K. Lo et al. (1999)

This is the study on route planning and guidance (RPG). This is a part of the Intelligent Transportation Systems of the user services in the United States. The concept of RPG is that “it would allow equipped vehicles to spread from the congested to the less congested areas” (Hong et al, 1999). The benefits of RPG services can either provide convenient or time savings to the users. However, system congestion is the side effect for RPG services. This raises a question on how the transportation management agency deals with such dilemma. With this in mind, the objective of this paper is to settle such dilemma through developing a model. Two criteria are delimited, one is an elastic market penetration of RPG services, while another is a bilevel program to minimize the travel time. Results show that it is not possible for the determination of a unique cost that would minimize the total system time for a wide range of demand levels. It is because the total demand inserts great influence on the performance of the systems.

The study of Dahlgren et al. (1996)

This study is derived from the case studies of Advanced Transportation Management and Information Systems (ATMIS). This is a kind of transportation management study by applying the information systems. This paper mainly concentrates in the study on two questions: the first question is on the method in implementing ATMIS services successfully; and the second question is on the strategy to make ATMIS become cost-effective. With these in mind, the objective of this study is to “employ case studies of actual ITS implementations to investigate the implementation process and the
potential for cost-effective ITS implementation" (Dahlgren et al., 1996).

For the case studies, it spans the study from a small county to a congested city. The study area is in the United States. A successful implementation of ITS in transportation is under several circumstances. The first one is a need for the implementation of ITS. "In the case of ATMIS, this is generally a need to reduce delay in a situation where congestion is widely perceived as a major problem; ATMIS has little appeal where people perceive little delay" (Dahlgren et al., 1996). Apart from need, leadership, information and funding are also important for the successful implementation of ITS in a transportation system.

This paper can only answer the first question but not the second one. It concluded that "ATMIS will be most extensively implemented in the most congested situations, generally cities in large metropolitan areas" (Dahlgren et al., 1996). However, this study did not provide any answers on the circumstances for the ITS implementation in a transportation system that brings the cost-effective benefit to the system.

The study of Xu et al. (1998)

This is the case study of applying Intelligent Transportation System (ITS) in the biggest city of China – Shanghai. Being the biggest city of China, the traffic load within the city of Shanghai is heavy and some traffic problems such as traffic jams, traffic accidents or environmental pollution etc are inevitable. With these in mind, this paper concentrates on the suggestion of applying ITS in transport studies in which the transport system can be benefited from it. It is especially important in some large cities with busy traffic flow
like USA and Japan. "America, Japan and countries of Europe have achieved abundant experience and greater economic effectiveness during their development of ITS. The development of China is in initial stage" (Xu et al., 1998).

3.3.2 Local Studies on transportation

This section reviews the studies on transportation within the realms of Hong Kong.

The study of Tong & Wong (1996)

This is the study on highway planning in Hong Kong. Having known that Hong Kong is a small city with heavy traffic load. It is ever changing and developing in a fast pace. So, the aims of this paper are "to review the current highway planning procedure in Hong Kong and to suggest modifications so that it is more suitable for cities with a rapidly developing and uncertain environment" (Tong & Wong, 1996). With this in mind, this paper only gives a review on the transportation planning policy in Hong Kong and provides suggestions for further studies on the issue of highway planning. The studies are the review on several aspects in The Comprehensive Transport Study (CTS) in Hong Kong. They are the objectives, estimation of planning parameters, travel demand model, travel characteristics surveys, transport network models, highway project evaluation and transport policy evaluation. After reviewing these studies, recommendations are suggested for further studies on highway planning.

The study of Wong & Thong(1998)

This study incorporated the multimedia information and GIS methods for the planning
of urban transportation systems. "The incorporation of images and video within transport planning can overcome the perceptual barrier to understand complex transport planning information such as traffic flow characteristics" (Wong & Thong, 1988). As a result, this paper mainly concentrates on the discussion of the database design and the process the study is conducted. It appeals to the transport planners of how the transport study can be conducted by applying the multimedia and GIS methods. Through the step by step description, the benefits generated from the application of GIS and multimedia in transportation study are reviewed.

The study of Wong & Yang (1998)

This is the study on the urban taxi services in Hong Kong. The operation of the taxi market is analyzed. An urban taxi model is introduced and the Hong Kong Island is employed for the empirical test against this model on the taxi market in Hong Kong. "...a network equilibrium model was developed to offer some interesting insights into the nature of the equilibrium of taxi services, and offer some policy-relevant results for decision making" (Wong & Yang, 1998). The methodology used in this study is the mathematical models. It takes the circulating and waiting time of taxi into consideration. These two factors tend to influence the services provided by taxis. Results show that "circulating and waiting within a zone while searching for passengers is about three times as that for interzonal traveling" (Wong & Yang, 1998). It is suggested that there is still room for the improvement of the information system among taxi drivers so as to minimize the circulating and waiting time for passengers.
3.4 Comments

When referring to section 3.3, it is obvious that there is a growing trend of using ITS in transport studies. It is especially the case in the foreign transport studies. This implies that applying ITS in transport study is a common phenomenon in some advanced foreign countries with congested traffic flow. It is not so common in the case of Hong Kong but its importance is growing gradually. It is because there is a growing awareness of the benefits brought by applying ITS in transport studies especially in a busy and congested urban city like Hong Kong. However, it is rare to find the study of accessibility in transportation by using GIS from the past transport studies. This is quite a new concept in measuring accessibility measures by applying GIS method in Hong Kong up to this moment.

3.5 Summary

Past studies of transport studies have been reviewed in this chapter. They include the foreign studies and some local studies. Both show that the use of ITS in transport studies become more important especially in an urban city with congested and busy traffic flow.
Chapter 4
Methodology

As mentioned in previous chapters, the transportation system in Hong Kong is mainly configured by the CTS1 and CTS2. In this chapter, the method in conducting this study is discussed in detail. It includes the evaluation of the selected accessibility indices for this study, an analysis of the database design and the required data types, the procedures in deriving the common factors and testing against the accessibility indices. In order to strengthen the understanding of this study, some underlying concepts have to be clarified in advance. These concepts include the study areas, the elements of UTMS, origin and destination, road network & public transit routes, and the means of public transits.

4.1 Study Area

Urban congestion had once been one of the major urban problems in Hong Kong since 1950s. In order to reduce urban congestion and distribute the population evenly, the New Town Development Program has been carried out by the New Territories Development Department (NTDD) since 1972. The concept of new town is borrowed from Britain. It is to build up a self-contained society with its own industrial, commercial and residential land uses in a place outside the urban area. It differs from satellite town in which it is a self-contained society without direct linkages with the urban area. The term “self-contained” means there are no commuting trips in terms of working, school, shopping and recreation.

There were eleven new towns in Hong Kong by the 1996 Population By-census. They are Kwai Chung, Tsuen Wan, Tuen Mun, Sha Tin, Tai Po, Fanling/Sheung Shui, Tsing Yi, Tseung Kwan O, Ma On Shan, Yuen Long and Tin Shui Wai. One common characteristic of these new towns is that they are all located in the New Territories. Among these, some are already established, such as Kwai Chung, Tsuen Wan, Tsing Yi and Sha Tin, while some are newly developed, such as Tseung Kwan O, Yuen Long and Tin Shui Wai etc.
However, the new towns in Hong Kong cannot attain the original goals to be self-contained. There are frequent commuting trips from the rural area to the major urban area. With these in mind, transportation planning is one of the agenda of the new town planning project. It determines not only the network linkages inside the district, but also to the rest of the territory.

In this study, two new towns with contrasting accessibility levels are selected. They are Shatin and Tseung Kwan O New Towns. Shatin is one of the already established new towns. According to the delimitation of the Planning Department, the boundary of Shatin New Town includes Tai Wai, Shatin, Fo Tan, the Chinese University of Hong Kong and Ma On Shan. The choice of Tseung Kwan O new town as another study area because the transport networks in this region makes a contrast with that of Shatin. In this study, it is hypothesized that Shatin, with more comprehensive network systems, is more accessible than Tseung Kwan O, a recently developed new town, ceteris paribus.

In other words, it is expected that the same accessibility measure will result in an index difference between Shatin and Tseung Kwan O. The gravity-type accessibility measures which have already been mentioned in chapter 2 will be tested. Since each accessibility index is related to the measurement of particular trips (school trips in this study) within the studied regions, it is worth introducing here those concepts related to trips and how these are defined and measured in this study first before explaining the implementation of selected accessibility measures.

The shape of the study areas has been reflected in the study of road network. The distribution of road network of an area is based on the shape of that area. For example, the pattern of road network in Shatin is elongated. It is consistent with the shape of Shatin. (Figure 4.2 shows the shape of Shatin).

4.2 Elements of UTMS

The underlying concept of this study mainly follows the Urban Transportation
Model System (UTMS). This model includes four basic elements, namely, trip generation, trip distribution, mode choice (or modal split) and trip assignment (or route choice) (Pas, 1995).

*Trip generation:* it determines the number of trips produced by and attracted to each traffic analysis zone. In another word, it involves the question of how many trips are made to and from each zone of the study area.

*Trip distribution:* it is the study of the allocation of each trip from the origin to the destination in the area under study.

*Modal split:* it involves the question of how people make up each trip. It is the choice of different transport modes traveling from the origin to the destination.

*Trip assignment:* it involves the choice of routes in traveling from the origin to the destination.

In fact, when measuring the accessibility level of Shatin and Tseung Kwan O, for whatever measure is adopted, one or more of the four elements of the UTMS has been incorporated. Among the various transport trips, only school trip of secondary school students is studied. This is defined as follows:

a) For trip generation, the study takes into account of school trips of secondary school students. The number of trips is determined by the daily school trips of students.

b) For trip distribution, it considers the allocation of trips. As mentioned, the emphasis of this study is to analyze the school trip. Thus, it is to study the students traveling to schools from different places they live in the same district. It differs from trip generation in that it carries the concept of origin and destination. It can demonstrate the distribution of school trips from the residential sites to the secondary schools. It measures the distances from each origin to all destinations.

c) For modal split, it involves the questions of how they choose among different transport modes. In this study, as the objective is to analyze the accessibility of
secondary school students, only public transits instead of private transits are considered. As it is a study within the same region, both bus and maxicabs (the only available forms of public transport in the two new towns) are included. The exclusion of PLBs is that this type of transport mode does not have fixed routings, and the fares, and frequency of services cannot be predicted.

d) For trip assignment, it is about the routes they choose in their school trips. In this case, it is the study of the routes of different public transits involved.

4.3 Origin and Destination

In one single trip, there is one origin and one destination. In the study of school trips, the origins are the residential sites while the destinations are the secondary schools. A Residential site may be the accumulation of several housing blocks; e.g. Sha Kok Estate is defined as a site. This type of site boundary information is provided by the Population and Census Department of the Hong Kong SAR Government. Both origins and destinations are within the same district – Shatin and Tseung Kwan O. When measuring the accessibility level of a region, all the possible trips between each origin and all destinations will be considered.

4.4 Public transits

In the measure of Martin & Dalvi, different transport modes are taken into consideration. With this in mind, different types of public transits will be considered in this study. It is assumed that most students will take the public transits instead of the private transits in making their school trips. As the school trip made for this study is confined within Shatin and Tseung Kwan O new towns, the public transit chosen are bus and maxicab only. They are chosen because these two types of public transits are more reliable in their services provided in terms of frequency, fares and routings. Public Light Bus is not chosen because its services do not meet those criteria. These two types of public transits associated with different speed. Hence, for every
accessibility measure, two accessibility levels of school trips (one for the bus and the other for the maxicab) will be derived separately.

In this study, walking has already been taken into consideration. As the travel distances between each origin to all destinations within each new town are measured, the value "0" implies "walking distance". It is because no travelling by public transits has been generated.

4.5 Possible Vs existing routes

The accessibility level derived depends not only on the accessibility measuring method, the type of trip and the mode taken but also on the existing road network and the routes already designed. Route design is the responsibility of the Transportation Department of the Hong Kong SAR Government. It normally takes into account the demand of passengers and the expected profit. As demand changes with the number of school students and population distribution, routes are often changed (added or cancelled) from year to year. Therefore in this study, two types of flow are involved. One is based on road network and another is public transit route. The difference between them is on the determination of routings. There is no limitation on the choice of routes under the case of road network while the flow is restricted on either the bus or maxicab routings under the case of public transit routes. This means that the distance generated from the previous case is the shortest distance. Both situations are considered in this study. The whole Shatin and Tseung Kwan O are taken as the sample areas for the study of road network. Because of the limitation of resources, only a portion of these two regions is analyzed under the study of public transit routes. Such selection is based on the results derived from the condition under the road networks.

As all the routings are mentioned in this study, no sampling has been occurred. So, there is 100% sampling case and no statistical method for sampling should be used.
4.6 Accessibility Measures

The accessibility indices selected in this study are all in the Gravity type measures. They carry the concept of spatial interaction. The selected indices are, namely, the study of Hansen, Ingram, Clark, Martin, the Comprehensive Transport Study in 1976 and Gutierrez & Gomez. There will be a brief explanation for the choice of each individual index. The independent factors that are relevant to this study would be examined one by one in detail.

4.6.a Hansen’s Measure

The contribution of Hansen’s measure of accessibility can give an insight of the exponent value that is not clearly defined in other papers concerning the measurement method of accessibility. The size of the activity can be in various forms, such as number of jobs for the measurement of ‘accessibility to employment’, annual retail sales for the measurement of ‘accessibility to shopping opportunities’, population for ‘accessibility to residential activity’. In this study, the number of school places at the destination is chosen as the “size of the activity” for the accessibility of school trips. The measurement method of Hansen had considered the factor of travel time. In transportation geography, it is important to consider the factor of time cost (travel time), distance cost (distance between the origin and the destination), and speed.

With these in mind, the independent factors in Hansen’s measure in this study would be as follows:

\[ A_i = \sum_{j=1}^{g} \frac{S_j}{T_{i,j}} \]  \hspace{1cm} (2.3)

where \( S_j \) represents the number of school places in each secondary school;
\( T_{i,j} \) represents the travel time generated from the origin to the destination; i.e. from each residential site to each secondary school;
\( x \) represents the calibration parameter.
Hansen’s measure of accessibility index is the summation of the number of school places divided by the travel time from the origin to the destination with the calibration parameter ($x$). When considering that the number of school places is constant in this equation, the accessibility level would be influenced by the change of the calibration parameter and the travel time from the origin to the destination. If the calibration parameter and the number of school places remain unchanged, the larger the travel time, the smaller the value of $Ai$ will be, meaning that it is less accessible. Hence, the smaller the value of $Ai$, the less accessible it is.

### 4.6.b Ingram’s Measure

In Ingram’s study, the calibration parameter in the equations was without much guidance of how this value is derived. The insight of Ingram was to take into account of the factor of barriers. He also suggested the use of straight line and rectangular distances between two points. For the technique of measuring integral accessibility, it is quite useful in measuring the accessibility of one set of points with respect to another set of points. This can be applied for analyzing the school trips generated from the origins (residential sites) to the destinations (secondary schools) because both residential buildings and secondary could be displayed as points on map.

Hence, the application of Ingram’s measure in this study is interpreted as follows:

In measuring relative accessibility, the formula would be:

$$Ai = \sum_{j=1}^{n} a_{ij}$$

(2.4)

where $a_{ij}$ is the relative accessibility between an origin and a destination.

The value of $a_{ij}$ selected in this study is the reciprocal function:

$$a_{ij} = 100 \cdot dij^{-x}$$

(2.6)
where $d_{ij}$ is the physical distance between the origin and the destination; $n$ represents the summation of $a_{ij}$ from $j=1$ to $n$ times.

In the case of relative accessibility, we have to consider various types of measures. They are the reciprocal function, negative exponential function and normal function. In this study, only the reciprocal function would be chosen. For the exponential function, it only emphasizes in measuring accessibility over short distances. So, it is not applicable in the case over longer distances. Actually, it is difficult to determine the length of distances (whether it is short or long) in a quantitative approach. To a certain extent, such measure creates restriction to the study over distance. Also, in the case of normal function, it includes the constant value in which it is not properly defined. Hence, it would not be a good indicator to be included in the analyzing process. As a result, the larger the $Ai$, the more accessible it is.

### 4.6c Clark’s Study

Clark’s formula took the factor of travel time and number of employment at the destination into consideration, since it carried the meaning of spatial interaction, it is applicable to this study.

The formula of Clark interpreted in this study is as follows:

$$A_i = \sum_j f(c_{ij})O_j$$

(2.9)

where $f(c_{ij}) = t_{ij}^{-1}$

$t_{ij} = \text{travel time between residential site and secondary school;}$

$O_j = \text{number of school places at the destination.}$

The equation hence can be rewritten as:
\[ A_i = \sum_{j}^{O_j/\ell_j} \]

"\( A \)" in this sense, represents the accessibility of school trips of residents.
This formula implies that if there is no change of the number of school places, the
longer travel time will give rise to a smaller value of \( A_i \) and vice versa. This means
that the larger the value of \( A_i \), the more accessible it is.

4.6.d The study of Martin and Dalvi:

The accessibility measurement method proposed by Martin and Dalvi is actually the
modification of Hansen's measure. It differs from Hansen's in that Martin and Dalvi
considered the factor of different modes of transport. This is more realistic because
there are actually more than one type of transportation modes within the whole
transportation system. As the aim of this study is confined to public transits, only
public transportation modes are considered.
The formula for this study is as follows:

\[ A_i^k = \frac{\sum_{j=1}^{W_j \exp(-\beta c_{ij}^k)}}{\sum_{j=1}^{W_j}} \]

(2.12)

where

\( A_i^k \) = accessibility afforded by mode \( k \) to household residents in each residential site;

\( W_j \) = number of school places at the destination;

\( c_{ij}^k \) = travel time generated from the origin to the destination by mode \( k \);

\( \beta \) = calibration parameter.

The value of \( A_i \) is determined by the values of parameter and the travel time from the
origin to the destination. In this sense, the larger the value of either the parameter or
the travel cost, the larger value the \( A_i \) will be.
4.6.e The Comprehensive Transport Study in 1976

The Comprehensive Transport Study in 1976 provided an indicator in measuring the accessibility level and a range to classify the accessibility level (2.13). Although this measure was derived before the construction of the railway systems and the development of new towns, it is the study in the setting of Hong Kong. Thus, it is selected again to investigate whether it can still reflect the transportation system in Hong Kong.

The formula used in this study is as follows:

\[
Ai = \left[ \frac{1}{M} \sum_{j=1}^{k} E_j T'_{i-j} \right]^{\gamma_x}
\]  

(2.13)

where

\( E_j \) = Number of school places at the destination;

\( T'_{i-j} \) = Travel time by public transport between the residential site and secondary school.

\( M = \sum_{j=1}^{k} E_j \)

\( x \) = calibration parameter.

4.6.f The study of Javier Gutierrez & Gabriel Gomez

In the study of Javier Gutierrez & Gabriel Gomez, three indicators in measuring accessibility level are selected, namely, Weighted Mean Travel Costs, Opportunity Accessibility and Economic Potential. However, only the indicators of the Weighted Mean Travel Costs and the Economic Potential provide the formula for calculation process. The indicator of Economic Potential borrowed the concept of the gravity type measurement method. Although it emphasized the factor of attractive masses of the
zones concerned, it measures the economic potential instead of accessibility. Hence, it is not selected. On the other hand, the Weighted Mean Travel Costs considered the factors of the travel time and the attractive mass of the destination. It would be selected as it measures the accessibility of a node.

The formula of the Weighted Mean Travel Cost used in this study is defined as follows:

*Weighted Mean Travel Costs:*

\[
A_i = \frac{\sum_{j=1}^{n} (T_{ij}X_{ij})}{\sum_{j=1}^{n} M_j}
\]  (2.14)

where,

- \( A_i \) = the accessibility of the residents in a region
- \( T_{ij} \) = the travel time through the network from the residential site to the secondary school;
- \( M_j \) = number of school places at the destination school.

This model does not consider the factor of calibration parameter. It takes the travel time and the attractive mass (number of school places) into consideration. Then the longer the travel time, the larger the \( A_i \) will be and vice versa. So, the large \( A_i \) implies that less accessible the place is.

With all these in mind, Figure 4.1 can summarize the concept mentioned above.
Figure 4.1 Flow chart for the underlying concept of this study.

The flow chart in Figure 4.1 summarizes the main concept of the methodology of this study. It is the study of accessibility measure for school trips. Some common factors among them can be found, namely, distance cost, time cost, activity base and calibration parameter. Origins and destinations are two elements that cannot be neglected for the analysis of accessibility measures. Origins are the residential sites while destinations are the secondary schools for this study. This study is conducted in two perspectives; one is conducted upon all possible routes on existing road network, while the other one based on existing routes of public transits. For the previous situation, both the accessibility levels of the modes of bus and maxicab are derived, while only the accessibility of bus is derived for the latter case.

4.7 Database Design

The data required in this study include land data and attribute data. Land data includes outline of the studied regions, road centerlines, the locations of the residential sites
and schools in Shatin and Tseung Kwan O. For the attribute data, it includes population, number of school places, and the names of road centerlines and residential sites. For the land data as well as the information of the names of schools and residential sites, they are extracted from the digital map data of the Land Information Center (LIC) of the Survey & Mapping Office, the Lands Department. Apart from these geographic features, both bus and maxicab terminus are needed. The routing of bus is provided by the Kowloon and Motor Bus Company while the routing of maxicab is from the Transport Department. As the number of school places of each school is not available, this set of data is collected by sampling. Lastly, population in Shatin and Tseung Kwan O are obtained from the 1996 Population By-census provided by the Census and Statistical Department. The use of 1996 Population By-census because it is the set of population more close to 1999 provided by the government.

A more detailed discussion on the format of the data provided and required, and the necessary transformations are presented in the following sections.

The digital map data provided by the LIC are in the scales of 1:1000, 1:5000, 1:10000 & 1:20000. They are divided into three systems; Digital Topographic Map Database (B), Digital Land Boundary Database (C) and Geo-reference Database (G). The details are shown in Table 4.1.

Table 4.1 Digital Data of Hong Kong from LIC.

<table>
<thead>
<tr>
<th>Category of Digital Data</th>
<th>Database Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Topographic Map Database</td>
<td>B1000 (Scale 1:1000)</td>
</tr>
<tr>
<td></td>
<td>B5000 (Scale 1:5000)</td>
</tr>
<tr>
<td></td>
<td>B10000 (Scale 1:10000)</td>
</tr>
<tr>
<td></td>
<td>B20000 (Scale 1:20000)</td>
</tr>
<tr>
<td>Digital Land Boundary Database</td>
<td>C1000 (Scale 1:1000)</td>
</tr>
<tr>
<td>Geo-Reference Database (G1000)</td>
<td>Building Polygon (BG1000)</td>
</tr>
<tr>
<td></td>
<td>Road Center Line (RG1000)</td>
</tr>
<tr>
<td></td>
<td>Site Polygon (SG1000)</td>
</tr>
</tbody>
</table>

Source: Land Information Center of the Hong Kong Administrative Region Government, 1999.
As mentioned, the land data of this study includes the outline of studied regions, road centerlines, and the locations of residential sites and schools. The B5000 series is adopted for such database creation. The B5000 digital maps are in the export format of ArcInfo (.e00). For each B5000 digital map, two feature layers are required: road and building.

4.7.1 Boundary of Studied Regions

For the region of Shatin, it includes nine map sheets of 1:5000, whereas three map sheets are needed for Tseung Kwan O. The command of ‘append’ of ArcInfo version 6.0 can be used in integrating the individual map sheets as one single map. The database of each individual map sheet has been combined into one after the process of integration. Figure 4.2 shows the base map of Shatin after integrating the individual maps. As the scale of 1:1000 road centerlines is used, knowing that 1mm=1m, the accuracy level of the result is within 1m.

Figure 4.2 Base map of Shatin.
4.7.2 Road Network

For the creation of the road centerlines, RG1000 digital maps are used. There are two types of file formats in RG1000; *.txt and *.sdf. The *.txt files contain label point coordinates, label ID and x, y coordinates which define the geometry of each road centerline. The file of *.sdf mainly includes names of streets. Examples of *.txt and *.sdf are shown in Figure 4.3 & 4.4.

```
1 (Label ID)
0.84250668119768000+06 0.82980310727828220+06
0.84251806721966600+06 0.8297923101968870+06
0.8425239745640300+06 0.82979861215260150+06
0.842512441734200+06 0.8297746861226530+06
0.8425076580270240+06 0.8297790988674620+06
0.8425062940119850+06 0.8297807602581750+06
0.842506350614290+06 0.8297824803747040+06
0.842504720457250+06 0.829784391380090+06
0.842504416333680+06 0.8297864748127300+06
0.8425045647021340+06 0.829788934566880+06
0.8425062525127370+06 0.829782494188890+06
0.84250668119768000+06 0.82980310727828220+06
END

2 (Label ID)
0.8424455243632020+06 0.82986133752586240+06
0.84245755716552840+06 0.8298511024270250+06
0.8424954361220030+06 0.8298232534703060+06
0.8424933259104450+06 0.8298148234911000+06
END

3 (Label ID)
0.8424943259184450+06 0.82980148234911000+06
0.84250668119768000+06 0.82980310727828220+06
END
```

Figure 4.3 Example of *.txt file for road centerlines, e.g. Road #2 is defined by 4 points (x, y coordinates).
<table>
<thead>
<tr>
<th>Street-ID</th>
<th>Street Code</th>
<th>Street Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.99</td>
<td>.99</td>
</tr>
<tr>
<td>2</td>
<td>.99</td>
<td>.99</td>
</tr>
<tr>
<td>3</td>
<td>.99</td>
<td>.99</td>
</tr>
<tr>
<td>4</td>
<td>.99</td>
<td>.99</td>
</tr>
<tr>
<td>5</td>
<td>.99</td>
<td>.99</td>
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<tr>
<td>6</td>
<td>.99</td>
<td>.99</td>
</tr>
<tr>
<td>7</td>
<td>35</td>
<td>AU PUI WAN STREET</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>AU PUI WAN STREET</td>
</tr>
<tr>
<td>9</td>
<td>35</td>
<td>AU PUI WAN STREET</td>
</tr>
<tr>
<td>10</td>
<td>1999</td>
<td>SHEK LAU TUNG STREET</td>
</tr>
<tr>
<td>11</td>
<td>498</td>
<td>FO TAN ROAD</td>
</tr>
<tr>
<td>12</td>
<td>754</td>
<td>HO LEK PUI STREET</td>
</tr>
<tr>
<td>13</td>
<td>754</td>
<td>HO LEK PUI STREET</td>
</tr>
<tr>
<td>14</td>
<td>2491</td>
<td>TSUNG TAU HA ROAD</td>
</tr>
<tr>
<td>15</td>
<td>498</td>
<td>FO TAN ROAD</td>
</tr>
<tr>
<td>16</td>
<td>190</td>
<td>CHEUNG LEK MEI STREET</td>
</tr>
<tr>
<td>17</td>
<td>498</td>
<td>FO TAN ROAD</td>
</tr>
<tr>
<td>18</td>
<td>2174</td>
<td>SUI WO ROAD</td>
</tr>
<tr>
<td>19</td>
<td>498</td>
<td>FO TAN ROAD</td>
</tr>
<tr>
<td>20</td>
<td>2913</td>
<td>YUEN WONG AU STREET</td>
</tr>
<tr>
<td>21</td>
<td>1389</td>
<td>MAN HANG STREET</td>
</tr>
<tr>
<td>22</td>
<td>1420</td>
<td>MIN FONG STREET</td>
</tr>
<tr>
<td>23</td>
<td>2174</td>
<td>SUI WO ROAD</td>
</tr>
</tbody>
</table>

Figure 4.4 Example of *.sdf file for road centerlines.

The data of road centerline provided by LIC is in non-generated format of x, y coordinates. The attribute tables and the label id are separated into two files. As a result, street names cannot be found in the *.txt files. Moreover, no nodes can be found in these centerlines and directions cannot be defined. All these missing elements are important for the database creation of road centerlines for this study. With these in mind, there is a need to generate the road centerlines data back into linear features, add the street names and build the nodes on the centerlines.

Over 100 sheets of RG1000 digital maps are required in this study. First, it is necessary to integrate the *.txt and *.sdf files of each individual map sheet through the Street-id as their common identifier. Then each map is generated back to its linear geometry with the Arc/Info version 6.0 command “generate” and “build” respectively. “Build” means building the road centerline topology. This is necessary because when referring to Figure 4.5, the integers in the column of From and To node are zero. It means that no nodes have been built on the road centerlines. The function of nodes on road centerlines can help identify the direction of the traffic flow. So, it is necessary to build nodes on the road centerlines for the determination of traffic directions. After building topology, there are “integers” associated with the columns of from-node and
to-node after the nodes. Figure 4.6 and Figure 4.7 show the database of the road centerlines before and after building nodes.

Figure 4.5 An example of a table after the linkages of *.txt and *.sdf files.

<table>
<thead>
<tr>
<th>Arc: list street.aat</th>
<th>6,000,001,024 bytes free</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNODE#</td>
<td>= 0</td>
</tr>
<tr>
<td>TNODE#</td>
<td>= 0</td>
</tr>
<tr>
<td>LPOLY#</td>
<td>= 0</td>
</tr>
<tr>
<td>RPOLY#</td>
<td>= 0</td>
</tr>
<tr>
<td>LENGTH</td>
<td>= 83.492</td>
</tr>
<tr>
<td>STREET#</td>
<td>= 1</td>
</tr>
<tr>
<td>STREET-ID</td>
<td>= 1</td>
</tr>
<tr>
<td>STREET-CODE</td>
<td>= 2304</td>
</tr>
<tr>
<td>STREET-NAME</td>
<td>= TAK HAU STREET</td>
</tr>
<tr>
<td>FNODE#</td>
<td>= 0</td>
</tr>
<tr>
<td>TNODE#</td>
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<td>LPOLY#</td>
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<td>= 112.241</td>
</tr>
<tr>
<td>STREET#</td>
<td>= 2</td>
</tr>
<tr>
<td>STREET-ID</td>
<td>= 2</td>
</tr>
<tr>
<td>STREET-CODE</td>
<td>= 2756</td>
</tr>
<tr>
<td>STREET-NAME</td>
<td>= OU CHE STREET</td>
</tr>
<tr>
<td>FNODE#</td>
<td>= 0</td>
</tr>
</tbody>
</table>

Continue?

Figure 4.6 The selected database of road centerlines before building the nodes.

<table>
<thead>
<tr>
<th>Arc: list street.aat</th>
<th>6,010,642,432 bytes free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record</td>
<td>FNODE# TNODE# LPOLY# RPOLY# LENGTH STREET# STREET-ID</td>
</tr>
<tr>
<td>1</td>
<td>0 0 0 0 0 0 62.709 1 1</td>
</tr>
<tr>
<td>2</td>
<td>0 0 0 0 0 21.766 2 2</td>
</tr>
<tr>
<td>3</td>
<td>0 0 0 0 0 65.910 3 3</td>
</tr>
<tr>
<td>4</td>
<td>0 0 0 0 0 63.095 4 4</td>
</tr>
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<td>5</td>
<td>0 0 0 0 0 34.395 5 5</td>
</tr>
<tr>
<td>6</td>
<td>0 0 0 0 0 73.209 6 6</td>
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<td>7</td>
<td>0 0 0 0 0 17.978 7 7</td>
</tr>
<tr>
<td>8</td>
<td>0 0 0 0 0 86.797 8 8</td>
</tr>
<tr>
<td>9</td>
<td>0 0 0 0 0 43.388 9 9</td>
</tr>
<tr>
<td>10</td>
<td>0 0 0 0 0 60.584 10 10</td>
</tr>
<tr>
<td>11</td>
<td>0 0 0 0 0 75.717 11 11</td>
</tr>
<tr>
<td>12</td>
<td>0 0 0 0 0 70.103 12 12</td>
</tr>
<tr>
<td>13</td>
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<td>0 0 0 0 0 102.241 17 17</td>
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<td>0 0 0 0 0 94.810 20 20</td>
</tr>
<tr>
<td>21</td>
<td>0 0 0 0 0 150.075 21 21</td>
</tr>
</tbody>
</table>

Continue?
There are also differences of the graphic display before and after building nodes on road centerlines. The differences are shown in Figure 4.8 and 4.9.
Figure 4.9 Sample of selected road centerlines after building nodes.

Having attached the database of *.sdf files to the *.txt files and built the nodes on road centerlines to each individual RG1000 digital map, it is necessary to integrate these individual road centerlines into a single centerline map for Shatin and Tseung Kwan O respectively. By using the same method in appending the base maps in section 4.7.1, the road centerlines of these two regions are formed. Figure 4.10 shows the road centerlines of Shatin.

Actually, the rationale for the study of road centerlines is based on the 1980 Hong Kong Grid System. It provides the (x,y) coordinate system. For this study, majority of them is the straight-line distance between nodes and along centerlines. Each segment is short enough so that the elevation distance is negligible.
Figure 4.10 Road centerlines of Shatin.

Figure 4.11 Sample of the selected database of road centerlines of Shatin.

As the base map and the road centerlines are in two layers, they can be overlaid together for data visualization by using ArcView 3.1 (Refer to Figure 3.1 for details).
4.7.3 Residential Sites (Origin) & Schools (Destination)

Residential Sites (Origin)

Residential sites form the origins for this study. Residential site is the grouping of residential buildings to form a site. For example, Sha Kok Estate in Shatin is categorized as a residential site. These residential sites provided by LIC are in polygon features. Figure 4.12 shows the example of residential sites in polygon format in Shatin.

![Figure 4.12 Example of selected residential sites in Shatin.](image)

In network analysis, origins have to be represented as points. In order to simplify the study, centroids of the residential sites are chosen as the origins. Figure 4.13 shows the centroids of the residential sites. The database of the residential sites after adding the centroids is shown in Figure 4.14.
Figure 4.13 Selected sample of the centroids of building sites as the origins in Shatin.

Figure 4.14 Selected sample of the database of residential sites in centroids in Shatin.

The used of centroids in this study is to measure the travel distance between origins and destinations. As centroid is the points in each residential site, these points will be snapped to the nearest stops on the centerlines for measuring the travel distance.
Schools (Destination)

The feature of schools forms the destination for this study. This set of data is in the format of point feature. As the school data from the LIC does not contain the information of school names and addresses, there is a need to add these data into the database of school. The database of school in Shatin is shown in Figure 4.15.

![Database of School in Shatin](image)

Figure 4.15 Selected sample of database of school in Shatin.

4.8 Derivation of Factors

As mentioned above, six accessibility indices are selected for this study. They all belong to gravity type accessibility models. These models carry the meaning of interaction between two places. Three common factors can be found in these indices: activity base; travel cost and calibration parameter. In order to solve the accessibility indices, these are defined in the way specific to the application of this study.
Activity base

Past studies defined activity base as the attractiveness of the destination. It can be the number of jobs, people etc. In this study, the application is to measure the accessibility level of school trip from one origin (residential site) to all destinations (schools) in the district. As a result, the activity base is defined as the number of students of each secondary school in these two study regions. For the number of school places, 30 schools are selected for study. It records the 1999 school population. The mean of these 30 schools is considered as the activity base for this study.

Travel cost

Travel cost can be in terms of time cost or distance cost. In this study, travel cost is dependent on the requirement of the formula concerned. For example, in Ingram’s measure, travel cost is measured in the form of distance cost. On the other hand, in the study of Martin and Dalvi, it is in terms of time cost generated by different public transits.

Calibration Parameter

There is a standard method in deriving the parameter for this study. It requires the networking and the O-D matrix of the regions. As it involves several formulae for the derivation, and the steps are rather complicated, this would be explained in detail in section 4.8.2.

As mentioned, the software of ArcView GIS version 3.1 with the networking extension is used in deriving the travel distance cost. The process of data preparation for this analysis is vital in deriving the value of travel distance. As a result, it is necessary to mention this process before discussing how the factors of travel distance is derived. There is details discussion of how the algorithm has been constructed in section 4.7.
4.8.1 Travel cost

As mentioned, travel cost can be in terms of time cost or distance cost in this study. The geographic information system is used in the process of deriving the travel cost. The ArcView GIS with its network analyst extension is used in deriving the travel distance.

4.8.1.a Derivation of travel distance cost

In deriving travel distance cost by the network analyst extension of ArcView GIS, the algorithm design is an important step for the analysis. It includes database design and the conversion of the raw data into desirable formats. It is assumed that this study is conducted on planar surfaces of both study areas. It is because the difference between a slope and a plane road surface is minor. For example, for a 1:10 slope, the difference is only about 0.05 when compared with a plane surface. In case of possible routes based on existing road network, travel distance cost is found based on the shortest possible path distance from the origin to the destination regardless of the modes of transport. In the ideal case, for every O-D pair, one single direct route is available. However, travel distance cost derived under the situation of existing public transits routes may not follow the shortest path distance. This is because shortest distance may not be the only goal of route planning of bus and maxicab. It is expected that it is less accessible than those derived based on road network only. The differences between these two cases can be better illustrated by the diagram in Figure 4.16.
Figure 4.16 Diagram illustrating the ideas under the cases of road network and public transit routes.

The concepts of travel flow under both situations are best illustrated in Figure 4.16. Origins and destinations can be found in this diagram. The line segments in black represent the shortest paths without specific routings while for those in green represent the routings under the case of public transits routes. Sometimes, the origins and the destinations are not on the centerlines. In such case, there is a mechanism that helps snap these points to the nearest centerlines. In the study of road network, the travel distance is measured along the line segments in black from an origin to the destination, while it flows along the green line segments under the case of existing public transit routes. In this sense, the travel distance from O1 to D1 is longer under the case of public transit routes than the case of road network.

If specific routes are considered, it is necessary to include the information of the route numbers passing through each particular centerline in the database. The sample database is shown in Figure 4.17.
Figure 4.17 Selected centerline database of Shatin.

Figure 4.17 shows the database of centerlines of Shatin. It differs from the database in Figure 4.11 in that it includes the information of direction and the routings of bus and maxicab passing through each particular centerline. The study of the flow along the public transit routes is analyzed based on this database. The information is shown in the last three columns in Figure 4.17 in form of “Oneway”, “Bus-routes” and “Maxicab-routes”. Bi-directional centerlines are annotated as B (both directions) whereas uni-directional centerlines are divided into FT (From node to To node) or TF (To node to From node).

As this study involves the flow from multiple origins to multiple destinations and it involves 115 origins and 100 destinations, much time can be saved by working out the results by programming. It is to modify the Avenue script which is the programming language of ArcView GIS in fulfilling such requirement. It helps run the flow from one origin to the rest of the destinations, and the loop continues until the last set of data has been processed. The total flow involved is 115 times 100. Besides, the script enables the users to choose the desirable layers as the origin and the destination. So, it is more flexible for any changes for the choice of origin or destination because they
are not fixed. A new table is created to store the result. The Avenue script is in Appendix I and the result table is shown in Figure 4.18.

![Table](image.png)

Figure 4.18 The Sample Results of Distance Cost.

The table above demonstrates that the unit of distance cost is in meters. This table can show the cost of school trip. It flows from each origin to the rest of the destinations. There is a loop in repeating the flow. The capture of the theme ID instead of the names can make it more presently in presenting the result.

### 4.8.1.b Travel time cost

Having derived the travel distance cost in section 4.8.1.a, travel time cost can be found when the speed is provided. As mentioned, the main difference between the case of existing road network and the case of public transit routes is on the choice of routings. Both the speeds of buses and maxicabs are considered. The sources are from the Kowloon and Motor Bus Company and the Transport Department of Hong Kong.
SAR Government. The average speed of bus is 17km/h and that for maxicab is 38km/h for maxicab. So, the time cost for public transits is in a range instead of a fixed integer. The selected database is shown in Figure 4.19.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ORIGIN</td>
<td>DESTINA</td>
<td>Bus Speed</td>
<td>(bus_distance:bus_time)</td>
<td>maxicab_dist:Maxicab Speed:time</td>
<td>marsh_place</td>
<td>parameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>3</td>
<td>8</td>
<td>10</td>
<td>3</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>11</td>
<td>12</td>
<td>3</td>
<td>12</td>
<td>13</td>
<td>3</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>15</td>
<td>16</td>
<td>3</td>
<td>16</td>
<td>17</td>
<td>3</td>
<td>18</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 4.19 Selected data of travel time cost of bus and maxicab in Shatin.

### 4.8.2 Calibration Parameter

Calibration parameter is an exponent factor appeared in various accessibility indices mentioned before. The use of calibration parameter is to generate the result which can be more representative in reflecting the real world situation (details of how the calibration parameter is derived will be shown in the following sections). There is a standardized method in deriving this parameter, but a networking system and an Origin-Destination matrix are required in the calculation process. The basic techniques in deriving the calibration parameter is analyzed in detail in this section.

Before going into details of how it is derived, some terms have to be defined in advance. This is an essential step for understanding how the calibration parameter is derived in the later parts.
Trip matrix

It is a more common way to use a trip matrix to represent trip pattern in a study. A general form of a two-dimensional trip matrix is in Table 4.2 as follows:

Table 4.2 An example of a two-dimensional trip matrix

<table>
<thead>
<tr>
<th>Destination</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>...j</th>
<th>...n</th>
<th>( \sum T_{ij} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( T_{11} )</td>
<td>( T_{12} )</td>
<td>( T_{13} )</td>
<td>...</td>
<td>( T_{1j} )</td>
<td>...</td>
</tr>
<tr>
<td>2</td>
<td>( T_{21} )</td>
<td>( T_{22} )</td>
<td>( T_{23} )</td>
<td>...</td>
<td>( T_{2j} )</td>
<td>...</td>
</tr>
<tr>
<td>3</td>
<td>( T_{31} )</td>
<td>( T_{32} )</td>
<td>( T_{33} )</td>
<td>...</td>
<td>( T_{3j} )</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>N</td>
<td>( T_{n1} )</td>
<td>( T_{n2} )</td>
<td>( T_{n3} )</td>
<td>...</td>
<td>( T_{nj} )</td>
<td>...</td>
</tr>
<tr>
<td>( \sum T_{ij} )</td>
<td>( D_1 )</td>
<td>( D_2 )</td>
<td>( D_3 )</td>
<td>...</td>
<td>( D_j )</td>
<td>...</td>
</tr>
</tbody>
</table>

The entity in the matrix represents the number of trips generated from one origin to another destination respectively. \( T \) is the result of the summation of total \( T_{ij} \):

Cost element

As trips involve cost, cost element should be evaluated. The cost element can be in distance, time or money units. There is a linear function in deriving the cost element. The formula is as follows:

\[
C_{ij} = a_i T_{ij} + a_2 T_{ij} + a_y w_{ij} + a_4 t_{ij} + a_5 F_{ij} + a_6 s_j + \delta
\]

where

\( T_{ij} \) is the in-vehicle travel time between \( i \) and \( j \);
$t_{ij}^w$ is the walking time to and from stops (station);
$t_{ij}'$ is the waiting time at stops;
$t_{uij}$ is the interchange time, if any;
$F_{ij}$ is the fare charged to travel between $i$ and $j$;
$\phi_j$ is a terminal (typically parking) cost associated with the journey from $i$ and $j$;
$\delta$ is a modal penalty, a parameter representing all other attributes not included in the
generalised measure so far, e.g. safety, comfort and convenience;
$a_{1..6}$ are weights attached to each element of cost; they have dimensions appropriate for
conversion of all attributes to common units, e.g. money or time. (Ortuzar, Willumsen, 1994)

The coefficients are changed when the cost is measured in different units as defined.
$a_{1..6}$ are in equal weighting in the calculation process. Only part of the factors are
selected, namely, $t_{ij}'$, $t_{uij}$, $F_{ij}$ and $\phi_j$. These factors are selected because they can be
collected in a more quantitative method based on the realms of this study.

**The Gravity Distribution Model**

This is a type of trip predicting model when any important changes have been taken
place in the network. According to Casey (1955), the gravity model in the simplest
form is as follows:

$$T_{ij} = \frac{\alpha P_i P_j}{d_{ij}^\beta}$$  \hspace{1cm} (4.1)

where $P_i$ and $P_j$ represent the population of the places of origin and destination, $d_{ij}$ is
the distance between $i$ and $j$, and $\alpha$ is a proportionality factor.

This model is further modified by modeling it by a decreasing function. It is rewritten
as:
\[ T_{ij} = \alpha O_i D_j f(c_{ij}) \]  \hspace{1cm} (4.2)

where \( f(c_{ij}) \) is a generalized function of the travel costs with one or more parameters for calibration. This can be in these formats:

**Exponential function:**

\[ f(c_{ij}) = \exp(-\beta c_{ij}) \]  \hspace{1cm} (4.3)

**Power function:**

\[ f(c_{ij}) = c_{ij}^{-\eta} \]  \hspace{1cm} (4.4)

**Combined function:**

\[ f(c_{ij}) = c_{ij}^{\eta} \exp(-\beta c_{ij}) \]  \hspace{1cm} (4.5)

**Calibration Techniques**

In this part, the technique in deriving the calibration parameter is introduced. This method is based on the idea of the terms described above in this chapter. According to Hyman (1969), there is an equation to represent a trip matrix as shown below:

\[ c(\beta) = \sum_{ij} [T_{ij}(\beta)c_{ij}] / T(\beta) = c^* = \sum_{ij} (N_{ij}C_{ij}) / \sum_{ij} N_{ij} \]  \hspace{1cm} (4.6)

There is an assumption that the initial estimation of \( \beta_0 = \frac{1}{c^*} \) when \( m = 0 \) is in the first round calculation. Then \( m = m + 1 \) with the estimate value of \( \beta_{m-1} \). He defined the rules that when compared the mean modelled trip cost \( c_m \) and \( c^* \), if the two values are
so close, then the value of $\beta_{m-1}$ is accepted as the value of parameter. If not, it has to assume that $m = 1$, the value of $\beta_m$ will be estimated as $\beta_{l=q} \frac{B_0}{c^*}$. If the values are not close to each other, then it is assumed that $m > 1$ and the value of $\beta$ is estimated as $\beta_{m+1} = \frac{(c^* - c_{m-1})/\beta_{q-1} - (c^* - c_m) \beta_m}{c_m - c_{m-1}}$. Through this trial and error process, the parameter can be found.

**Derivation of the calibration parameter**

In this study, the calibration parameter is derived by using the techniques mentioned above. As the techniques have been described in detail in the above section, the procedure in deriving the calibration parameter is described in brief in the following section.

Firstly, a two-dimensional trip matrix has been prepared. This records the number of trips from each origin to the rest of the destinations. The second element is to derive the cost element. As mentioned, it can be in terms of time, distance or money units. In this study, the cost element is in time unit. When referring to the cost function, there are more than one elements in the equation. However, only some of the items are applicable in this study. In this sense, only those relevant items are counted and form the cost element. It then moves into the steps of deriving the value of the calibration parameter. It is a process of substituting the relevant variables into the equations provided. As it involves repeated steps of trial and error and quite a large amount of data has to be processed, it is a more convenient and timesaving method to do it through running a program. The profile of the program and the results are exemplified in Figure 4.20 and 4.21 below.
Figure 4.20 A tailor-made table for running the parameter.

<table>
<thead>
<tr>
<th>origin</th>
<th>dest</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>

Go

Figure 4.21 The result table displaying the value of the calibration parameter.

<table>
<thead>
<tr>
<th>T</th>
<th>13053.0200</th>
</tr>
</thead>
<tbody>
<tr>
<td>C*</td>
<td>2734.18680991095700000</td>
</tr>
<tr>
<td>B0</td>
<td>0.000365739457295000</td>
</tr>
<tr>
<td>B1</td>
<td>0.000000000004892300</td>
</tr>
<tr>
<td>B2</td>
<td>0</td>
</tr>
<tr>
<td>B3</td>
<td>-7475778.511491190000000000</td>
</tr>
<tr>
<td>B4</td>
<td>-4.1780075402795300000000000000000E+20</td>
</tr>
<tr>
<td>B5</td>
<td>-4.1795356022854800000000000000000E+20</td>
</tr>
<tr>
<td>B6</td>
<td>-4.1795356022854800000000000000000E+20</td>
</tr>
<tr>
<td>B7</td>
<td>-4.1795356022854800000000000000000E+20</td>
</tr>
<tr>
<td>B8</td>
<td></td>
</tr>
<tr>
<td>B9</td>
<td></td>
</tr>
<tr>
<td>B10</td>
<td></td>
</tr>
</tbody>
</table>
4.9 Testing against the accessibility indices

Having derived the required independent variables and the calibration parameter above, the accessibility indices can be tested. The testing procedure involves repetition of substituting the relevant data from the database. In facilitating the complicated calculation process, a calculation program by the language of Visual FoxPro is prepared. The profile is in Figure 4.22 below.

![Figure 4.22 A Visual FoxPro program for testing the accessibility indices.](image)

The result of each accessibility index is presented in the table format as shown in Figure 4.22 above. The transportation main table contains the database required for testing the individual accessibility index. The calculation program can automatically select the required items from the transportation main table to substitute into the index in concern. So, the main table is the base to contain the data for the calculation process of the indices.
4.10 Summary

Figure 4.23 Layout of the main concept of this study.

The structure of this study is shown in the flow chart in Figure 4.23. In this study, several accessibility indices are selected as the testers in the regions of Shatin and Tseung Kwan O for empirical studies. Some common factors can be found among these accessibility indices, such as travel cost, calibration parameter and activity base. The GIS software ArcView version 3.1 and its extension Network Analyst are used for deriving the travel distance cost. Before that a database for network analysis is required. It includes the data of base maps, centerlines, building sites and schools of Shatin and Tseung Kwan O respectively. The method provided by Hyman (1969) helps derive the value of calibration parameter. For the value of activity base, its value is derived by the method of sampling. The values of these common factors are important elements for deriving the values of accessibility indices.

To summarize, this chapter has details discussion on how this study is conducted and the methods involved. It includes the evaluation of the selected accessibility indices, discussion of the derivation of the common factors, and the process of how these
indices are tested. The values of accessibility indices can be found and the result is presented in chapter 5.
CHAPTER 5
RESULTS AND ANALYSIS

The procedures in deriving the accessibility level of each accessibility index have been discussed in detail in chapter 4. So, the results are presented in this chapter. But first of all, an empirical testing against the hypothesis has to be mentioned in section 5.1. This helps strengthen the understanding of the results presented in sections 5.2.1 and 5.3.1.

5.1 Results Vs Hypothesis

A hypothesis is made in this study in Chapter 4. The hypothesis in P.34 implies that the network systems in Shatin have been developed more completely than those in Tseung Kwan O. With this in mind, it is hypothesized that “the students living in Shatin to schools are more accessible than those living in Tseung Kwan O, ceteris paribus.” As a result, this section is to test against this hypothesis by real world data. The data is the supply of public transits and the demand generated by the school population within these two regions. This section provides the criteria for result analysis.

5.1.1 Real World Data Testing Against the Hypothesis

The hypothesis in this study is made based on the stages of new town development. Actually, this is not a quantitative problem over the issue of how much Shatin is more accessible than Tseung Kwan O. With this in mind, the hypothesis may be supported by the method of counting the numbers of bus and maxicab routings travelling within these two regions. It becomes a more quantitative way to test against the hypothesis. The use of this method is consistent with the objectives and the realms of this study. So, only the numbers of routings of these two types of public transits are considered.
Supply Side

According to the data provided by the Kowloon Motor Bus Company, there are 77 routings of bus in Shatin while there are only 24 routings in Tseung Kwan O. For the number of maxicab routings, there are about 22 routings in Shatin while there are 18 routings in Tseung Kwan O. Obviously, the routings of bus outnumber than that in Tseung Kwan O. It is about three times more. However, the difference is not so great in the case of maxicab routings. They are summarized in Table 5.1 below.

<table>
<thead>
<tr>
<th></th>
<th>Numbers of bus routings</th>
<th>Numbers of maxicab routings</th>
<th>Relative difference of bus (%)</th>
<th>Relative difference of maxicab (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shatin</td>
<td>77</td>
<td>22</td>
<td>68.83*</td>
<td>18.18*</td>
</tr>
<tr>
<td>Tseung Kwan O</td>
<td>24</td>
<td>18</td>
<td>-220.83**</td>
<td>-22.22**</td>
</tr>
</tbody>
</table>

Source: Kowloon Motor Bus Company.
*Relative difference of Shatin with respect to Tseung Kwan O of bus routings in %.
**Relative difference of Tseung Kwan O with respect to Shatin of maxicab routings in %.

Demand Side

The use of relative difference in comparing these two sets of data in Table 5.1 can make the comparison become more quantitative. Obviously, Table 5.1 shows that the relative difference of bus in Shatin with respect to Tseung Kwan O exceeds that of maxicab about three times. This implies that the provision of bus routings relative to that of maxicab in Tseung Kwan O is smaller. However, it is not persuasive to judge that there is insufficient supply of public transits in Tseung Kwan O by just referring to Table 5.1. This is because Table 5.1 only provides the supply side information. Hence, the total population of these two regions is needed. As it is the study of school trips, the targeted population is the school students aged between 8 and 15 (based on the 1996 Population By-census). When projected to year 2000, the targeted population is between the age of 12 and 15. The population of these two regions is summarized in Table 5.2 below.
Table 5.2 A summarized table of secondary school population in Shatin and Tseung Kwan O in year 2000.

<table>
<thead>
<tr>
<th></th>
<th>Targeted population aged between 12 and 19 (p)</th>
<th>Total population (P)</th>
<th>p:P (%)</th>
<th>Relative difference of the targeted population (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shatin</td>
<td>96,793</td>
<td>582,993</td>
<td>16.60</td>
<td>70.70*</td>
</tr>
<tr>
<td>Tseung Kwan O</td>
<td>28,340</td>
<td>197,876</td>
<td>14.32</td>
<td>-241.35**</td>
</tr>
</tbody>
</table>

Source: 1996 Population By-census from the Census and Statistics Department Hong Kong.

*Relative difference of targeted population of Shatin with respect to Tseung Kwan O in %.
**Relative difference of targeted population of Tseung Kwan O with respect to Shatin in %.

Table 5.2 shows the population data of Shatin and Tseung Kwan O as extracted from the 1996 Population By-census. The first two columns are the raw data of the numbers of the targeted population and the total population respectively. The third column is the relative percentage of the targeted population to the total population of each region (p:P). It is to demonstrate the relative importance of the targeted population when compared with the total population. For the fourth column, it is the relative difference of the targeted population. One is from the perspective of Shatin to Tseung Kwan O, and the other is the reverse. This can display the relative difference of the targeted population between Shatin and Tseung Kwan O.

The data in Table 5.2 shows that both the number of the targeted and the total population in Shatin exceed those in Tseung Kwan O by a large extent. However, when the percentage of the relative rate of the targeted population to the total population is considered, it shows that the difference between Shatin and Tseung Kwan O is small. It is 16.6% for Shatin while it is 14.32% for Tseung Kwan O. The difference is only 2.28%. As the population of both regions are in the year of 1996 Population By-census, it is predicted that there is room for the growth of the targeted population in both regions. It is especially the case for Tseung Kwan O because it is still under the developing stage. However, when referring to Table 5.1, the supply of bus routings in Tseung Kwan O is much smaller than those in Shatin. In this sense, the real world situation confirms the hypothesis. These give rises to the conclusion
that the students in Shatin are more accessible than those in Tseung Kwan O to a large extent is correct.

As the hypothesis is constructed based on the real world situation of Hong Kong, only those indices that are satisfied with such conclusion are selected for further elaboration in section 5.2.

5.2 Results derived from possible routes

As mentioned in section 4.5 in chapter 4, this study conducted in two dimensions. One is based on the existing road networks while the other is based on the existing routes. For the previous case, it is assumed that the values of accessibility index measured in such a way implies that it is the shortest path being traversed by bus or maxicab regardless of their existing routings. The whole regions of Shatin and Tseung Kwan O are tested empirically under the existing road networks. The results are shown in section 5.2.1. For the latter case, the routes are mainly planned by the bus companies in concern. In most cases, the aim of the routes planning is to maximize the carrying capacity instead of choosing the shortest path to travel. Hence, the existing public transit routes do not necessary imply the shortest path. A selected region, (New Town Plaza) of Shatin and (Metro City) of Tseung Kwan O are tested empirically under the existing public transit routes. Their results are shown in sections 5.2.2 and 5.3.1 respectively.

As this study considers bus and maxicab as the public transits in Shatin and Tseung Kwan O, it involves two speeds for deriving the travel time cost for the two modes. This provides a range for travel time costs and accessibility levels associated with it is different.
5.2.1 Comparisons of Accessibility measures based on the existing road networks

The results derived for different accessibility measures based on existing road network are shown from Figures 5.1a to 5.6b.

Figure 5.1a The accessibility in Shatin derived by the measure of Hansen.

Figure 5.1b The accessibility in Tseung Kwan O derived by the measure of Hansen.
Figure 5.2a The accessibility in Shatin derived by the measure of Ingram.

Figure 5.2b The accessibility in Tseung Kwan O derived by the measure of Ingram.

Figure 5.3a The accessibility in Shatin derived by the measure of Clark.
Figure 5.3b The accessibility in Tseung Kwan O derived by the measure of Clark.

Figure 5.4a The accessibility in Shatin derived by the measure of Martin & Dalvi.

Figure 5.4b The accessibility in Tseung Kwan O derived by the measure of Martin & Dalvi.
Figure 5.5a The accessibility in Shain derived by the measure of CTS1.

Figure 5.5b The accessibility in Tseung Kwan O derived by the measure of CTS1.

Figure 5.6a The accessibility in Shatin derived by the measure of Gutierrez & Gomez.
Figure 5.6b The accessibility in Tseung Kwan O derived by the measure of Gutierrez & Gomez.

The figures above show the accessibility level derived by each accessibility index by using mode bus or maxicab under the situation of travelling along existing road network. There are two figures associated with each measure. One represents the accessibility level of Shatin while another represents that of Tseung Kwan O. The vertical scale of each graph represents the percentage (%) of the accessibility level while the horizontal scale represents the public transit modes considered in this study. Each of the accessibility measure is categorized into different classes which are indicated in legend of each graph. The rationale in dividing the class interval is to show the majority distribution of the data. The percentage in y-axis is the summation of all the origins into 100% and classified them into different intervals as shown in the legend. For example, in Figure 5.1a, 97% of the origins fall in the class of accessibility level between 1118 and 1122 for both bus and maxicab. Only bus and maxicab are considered as the public transit modes for this study as mentioned before. All these figures show the distribution and concentration pattern of the accessibility level derived by each measure of the related modes in concern. The legend shows the ranges of the accessibility level and they are associated with different colors.

In analyzing the strength of different accessibility indices, the method of inter-comparison among the accessibility indices is one way to demonstrate their differences. This can be measured by means of the “relative rate of accessibility differences”, as shown in the following equation:
\[ A_r = \frac{A_{Sm} - A_{TkO}}{A_{Sm}} \times 100\% \]  \hspace{1cm} (5.1)

where

\( A_r \) is the relative rate of accessibility differences;

\( A_{Sm} \) is the Accessibility in Shatin;

\( A_{TkO} \) is the Accessibility in Tseung Kwan O.

Equation (5.1) is derived with the assumption that Shatin is more accessible than Tseung Kwan O. With this in mind, Accessibility in Shatin is used as the base in equation (5.1).

The values of the relative rate of the accessibility differences are summarized in Table 5.3 below.

<table>
<thead>
<tr>
<th></th>
<th>( A_r ) of bus (%)</th>
<th>( A_r ) of maxicab (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hansen's measure</td>
<td>1.805</td>
<td>1.804</td>
</tr>
<tr>
<td>Ingram's measure</td>
<td>82.24</td>
<td>82.24</td>
</tr>
<tr>
<td>Clark's measure</td>
<td>58.59</td>
<td>57.87</td>
</tr>
<tr>
<td>Martin &amp; Dalvi's measurement</td>
<td>-0.29</td>
<td>-0.13</td>
</tr>
<tr>
<td>Measure of CTS1</td>
<td>-1.83</td>
<td>-1.83</td>
</tr>
<tr>
<td>Gutierrez &amp; Gomez's measure</td>
<td>55.74</td>
<td>55.74</td>
</tr>
</tbody>
</table>

Table 5.3 shows the results of the comparison between different indices in the relative rate of accessibility differences. The results are derived by using the equation (5.1). As mentioned before, the rule in defining the accessibility for the measures of Hansen, Ingram and Clark in Table 5.3 is that the larger the \( Ai \), the more accessible the place is, while the reverse is the case for the measure of Martin & Dalvi. So, \( A_r \) is in positive values for the measures of Hansen, Ingram and Clark while, it is in negative value for the measure of Martin & Dalvi. There are two columns in Table
5.3; one is the relative rate of accessibility differences of mode bus, while another is in mode maxicab. The difference between these two columns is on the transportation modes only. The values of $A_i$ review the extent of how Shatin is more accessible than Tseung Kwan O.

Generally speaking, all these graphs are categorized into different ranges in accordance with their minimum and maximum values in concern. The percentage can show the trend of their concentration and distribution. Comparison is made between Shatin and Tseung Kwan O for each measure. Mean value and standard deviation (s.d.) of the accessibility level are useful elements in such comparison process. Mean value of accessibility level is derived by taking its average value from the population, while s.d. shows the deflection value from the mean value. In the determination of the use of mean value for inter-region comparison on their accessibility level of each measure is mainly dependent on their s.d. values. The mean value is used for comparison only when s.d. value is small when compared with its mean. With these in mind, the mean and the s.d. values of the six accessibility measures of Shatin and Tseung Kwan O are shown in Table 5.4 and Table 5.5 respectively.

<table>
<thead>
<tr>
<th>Accessibility Indices</th>
<th>Mean of bus</th>
<th>s.d. of bus</th>
<th>Mean of maxicab</th>
<th>s.d. of maxicab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hansen</td>
<td>1119.508</td>
<td>0.113411</td>
<td>1119.838</td>
<td>0.11342</td>
</tr>
<tr>
<td>Ingram</td>
<td>10667.8256</td>
<td>1.075437912</td>
<td>10667.8256</td>
<td>1.075437912</td>
</tr>
<tr>
<td>Clark</td>
<td>15381.09</td>
<td>9557.353</td>
<td>34009.96</td>
<td>19934.79</td>
</tr>
<tr>
<td>K.M. Martin</td>
<td>0.994518</td>
<td>0.001892</td>
<td>0.997542</td>
<td>0.000849</td>
</tr>
<tr>
<td>CTSI</td>
<td>0.982287</td>
<td>0.001606</td>
<td>0.981997</td>
<td>0.001605</td>
</tr>
<tr>
<td>Gutierrez &amp; Gomez</td>
<td>15.78629</td>
<td>3.964478</td>
<td>15.78629</td>
<td>3.964478</td>
</tr>
</tbody>
</table>
Table 5.5 A summarized table for the results of Tseung Kwan O.

<table>
<thead>
<tr>
<th>Accessibility Indices</th>
<th>Mean of bus</th>
<th>s.d. of bus</th>
<th>Mean of maxicab</th>
<th>s.d. of maxicab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hansen</td>
<td>1099.297</td>
<td>0.13423</td>
<td>1099.622</td>
<td>0.134307</td>
</tr>
<tr>
<td>Ingram</td>
<td>1894.827</td>
<td>0.2545</td>
<td>1894.827</td>
<td>0.2545</td>
</tr>
<tr>
<td>Clark</td>
<td>6369.931</td>
<td>3414.417</td>
<td>14328.12</td>
<td>7767.672</td>
</tr>
<tr>
<td>K.M. Martin</td>
<td>0.99744</td>
<td>0.000728</td>
<td>0.998853</td>
<td>0.000326</td>
</tr>
<tr>
<td>CTSI</td>
<td>1.000639</td>
<td>0.000119</td>
<td>1.000344</td>
<td>0.000122</td>
</tr>
<tr>
<td>Gutierrez &amp; Gomez</td>
<td>6.986725</td>
<td>1.989105</td>
<td>6.986725</td>
<td>1.989105</td>
</tr>
</tbody>
</table>

When referring to Table 5.4 & 5.5, there are two indices that possess a large value of s.d. for both bus and maxicab. They are the measures of Clark and Gutierrez & Gomez. The wide range of s.d. values is because they are derived by different equations. This implies that these values cannot be compared directly. Instead, they can be compared by their implicit meaning of each equation associated with it (will be discussed in details in section 5.2.2). As mentioned before, a large value of s.d. tends to influence the reliability of using the mean value to represent the whole data set. As a result, it is necessary to analyze the components of these indices in order to find out the reasons for such large s.d. values.

With these in mind, a detail evaluation of the components of these indices is necessary. The accessibility indices of Clark and Gutierrez & Gomez are shown below.

*Clark's measure of accessibility*

\[
A_i = \sum_j \frac{O_j}{t_{ij}}
\]  
(2.7)

where

"A" in this sense, represents the accessibility of the residents at i.

\(t_{ij}\) = travel time between residential site and secondary school

\(O_j\) = number of school places at the destination.
Gutierrez & Gomez's measure of accessibility

\[ A_i = \frac{\sum_{j=1}^{a} (T_{ij}X_{M_j})}{\sum_{j=1}^{a} M_j} \]  \hspace{1cm} (2.11)

where

\( A_i \) = the accessibility of the residents from a residential building site

\( T_{ij} \) = the travel time through the network from the residential building to the secondary school

\( M_j \) = number of school places of the destination school

When referring to the accessibility index of Clark and Gutierrez & Gomez, both indices contain the common components, -- travel time and activity base of the destination. For the Clark's index, \( A_i \) and \( t_{ij} \) maintain an inverse proportional relationship with each other when the factor of activity base remains constant. This implies that the smaller the value of \( t_{ij} \), the larger \( A_i \) is. For the accessibility of Gutierrez & Gomez, \( A_i \) and \( t_{ij} \) hold a direct proportional relationship with each other when the factor of activity base remains constant. This means that the larger the value of \( t_{ij} \) tends to contribute to a larger \( A_i \).

The phenomenon above implies that the factor of time plays an important role for these two indices. A slight fluctuation of the value of time element tends to contribute to a great fluctuation of the accessibility level. So, this can explain why there are great fluctuations of the accessibility level and a large accessibility value of s.d. in both cases.

For the rest of the four accessibility indices, the s.d. values are small when compared with the mean values in concern. As this study only considers the road networks regardless of the public transit routes, the routing for bus and maxicab are assumed the same. The only difference between these two types of public transits is on the speed in concern. Among these four measures, only the measure of Ingram considered distance cost rather than time cost. For the remaining three measures, they consider
the time cost. So, the accessibility level generated by either type of public transits is the same under the case of Ingram and there are some differences for the rest of the three measures. A common phenomenon can be found from these three measures is that the accessibility level of Shatin and Tseung Kwan O is more or less the same. This phenomenon implies that the factor of time cost plays a less important role in these three measures than in the case of Clark and Gutierrez & Gomez as mentioned above.

5.2.2 Results analysis

The results presented in section 5.2.1 not only can show the distribution of the data, but also can review the accessibility level of Shatin and Tseung Kwan O for each individual measure. Different accessibility measures have different standards in determining whether the place is more accessible or not.

5.2.2.1 Hansen’s measure

There are two figures associated with the measure of Hansen. When referring to Figure 5.1a, the accessibility level of Shatin is in the range between the level of less than 1118 and 1134. Five intervals can be divided and 97% concentrates in the range between “1118 and 1122” for both bus and maxicab. In Figure 5.1b, the distribution of bus and maxicab are different from the case of Shatin. The accessibility level of Tseung Kwan O is in the range between the level less than “1099 and 1099.8”. Similarly, five intervals can be divided. 56% concentrates in the range between 1099.2 and 1099.4 for the case of bus while 78% concentrates in the range between 1099.6 and 1099.8 for the case of maxicab.

In Hansen’s measure, the larger the value of \( A_i \), the more accessible it is. It implies that when the accessibility value of one region is larger than the other, it can be said that it is relatively more accessible and vice versa. As stated above, the mean value of accessibility at Shatin for bus and maxicab are 1119.508 and 1119.833 respectively.
while they are 1099.297 and 1099.622 in Tseung Kwan O. In this sense, no matter what type of modes the students take, those students living in Shatin are more accessible than those in Tseung Kwan O in their schooling trips from the places they live.

5.2.2.2 Ingram’s measure

Figure 5.2a and Figure 5.2b show the accessibility level of Shatin and Tseung Kwan O derived by Ingram’s measure. In Figure 5.2a, the accessibility level of Shatin is in the range between the level of less than 3000 and 9000. Four intervals can be divided and 70% concentrates in the range between 3000 and 5000 for both bus and maxicab. In Figure 5.2b, the accessibility level of Tseung Kwan O is in the range between the level of less than 1894 and 1895.5. Similarly, four intervals can be divided and 71% of them concentrate in the range between 1894.5 and 1895 for both bus and maxicab.

As mentioned in section 4.2 in chapter 4, this study only considers the reciprocal function of accessibility of Ingram’s measure. In this sense, the larger the \( A_i \), the more accessible it is. This means that when the accessibility level of that place is larger, the more accessible the place is. The mean accessibility value in Shatin for both bus and maxicab is 10667.825 while, the value in Tseung Kwan O is 1894.827. In such comparison, the mean accessibility value in Shatin is larger than that of Tseung Kwan O. According to the rule of Ingram, the students of Shatin are more accessible than those in Tseung Kwan O.

5.2.2.3 Clark’s measure

The accessibility level of Shatin and Tseung Kwan O derived by the measure of Clark is shown in Figure 5.3a and Figure 5.3b. In Figure 5.3a, the accessibility level is in the range between the level less than 200000 and 100000 or above. Six intervals can be divided and 83% concentrates in the interval of less than 20000 for bus while 59% concentrates in the range between 20000 and 40000 for maxicab. In Figure 5.3b, the
accessibility level of Tseung Kwan O is in the range between the level of less than 5000 and 20000 or above. Five intervals can be divided and 89% concentrates in the level less than 10000 for bus but it is in a more even distribution for the case of maxicab.

The mean accessibility value of bus and maxicab in Shatin are 15381.09 and 34009.96 while, they are 6369.931 and 14328.12 in Tseung Kwan O. When referring to Clark’s accessibility index, the larger the value of $Ai$, the more accessible it is and vice versa. Obviously, both the mean accessibility values of bus and maxicab in Shatin are larger than those in Tseung Kwan O. It implies that the accessibility levels of the residents in Shatin is higher than those living in Tseung Kwan O.

5.2.2.4 Measure of Martin & Dalvi

The results of Shatin and Tseung Kwan O derived by the measure of Martin & Dalvi are presented in Figure 5.4a and Figure 5.4b. In Figure 5.4a, the accessibility level of Shatin is in the range between the level of less than 0.99 and 1. Three intervals are derived and 100% concentrates in the range between 0.99 and 1 for both bus and maxicab. In Figure 5.4b, the accessibility level of Tseung Kwan O is in the range between the level less than 0.996 and 1. Again, three intervals can be divided and 78% concentrates in the range between 0.996 and 0.998 for bus while 100% concentrates in the range between 0.998 and 1 for maxicab.

According to the rules of Martin and Dalvi, the larger the value of $Ai$, the less accessible it is and vice versa. With these in mind, when compared the mean accessibility levels of these two regions by modes, the values in Tsueng Kwan O for both bus and maxicab are larger than those in Shatin. This phenomenon implies that the accessibility level of the students in Shatin is better than those in Tseung Kwan O by the method of Martin and Dalvi.
5.2.2.5 Measure of CTS1

Figure 5.4a and Figure 5.4b show the accessibility level of Shatin and Tseung Kwan O derived by the measure of CTS1. In Figure 5.4a, the accessibility level of Shatin is in the range between the level of less than 0.97 and 0.985. Four intervals are divided and 97% concentrates in the range between 0.98 and 0.985 for both bus and maxicab. In Figure 5.5b, the accessibility level of Tseung Kwan O is in the range between the level of less than 1.0005 and 1.0009. Three intervals are divided and 88% concentrates in the range between 1.0005 and 1.0009 for bus while 88% concentrates on the level below 1.0005 for maxicab.

The mean accessibility values of bus and maxicab in Shatin are 0.982287 and 0.981997 while, they are 1.000639 and 1.000344 at Tseung Kwan O respectively. According to the theory of CTS1, there is a set of ranges in indicating the accessibility levels as stated in chapter 2. The classification indicates that the accessibility of 0-24 in range 1 represents Very High Accessibility. When referring to the case of Shatin and Tseung Kwan O, both the bus and maxicab fall in this range. This implies that both regions obtain very high accessibility. There are no big differences of the accessibility levels between these two regions.

5.2.2.6 Measure of Gutierrez & Gomez

The results of Shatin and Tseung Kwan O are presented in Figure 5.6a and Figure 5.6b. In Figure 5.6a, the accessibility level of Shatin is in the range between the level less than 10 and 30. Three intervals can be divided and 83% concentrates in the range between 10 and 20 for both bus and maxicab. In Figure 5.6b, the accessibility level of Tseung Kwan O is in the range between the level of less than 5 and 13. Again, three intervals can be divided and 78% concentrates in the range between 5 and 9 for both bus and maxicab.

The theory of Gutierrez & Gomez states that the larger the value of \( A_i \), the less accessible it is, and vice versa. Obviously, the mean accessibility value in Shatin is
larger than that in Tseung Kwan O. According to the logic of Gutierrez & Gomez, the accessibility of the residents in Tseung Kwan O is higher than those in Shatin.

A summarized table for the results in section 5.2.2 is shown in Table 5.6.

Table 5.6 The results of the accessibility measures under the situation of road network.

<table>
<thead>
<tr>
<th>Accessibility Indices</th>
<th>Hansen's Measure</th>
<th>Ingram's Measure</th>
<th>Clark's Measure</th>
<th>Martin's Measure</th>
<th>CTS1</th>
<th>Gutierrez &amp; Gomez's Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shatin is more accessible than Tseung Kwan O</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shatin and Tseung Kwan O are equally accessible.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Tseung Kwan O is more accessible than Shatin.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.6 summarizes the results of accessibility measures under the situation of existing road network. For the indices of Hansen, Ingram, Clark, and Martin & Dalvi, they fall in the first category; i.e. Shatin is more accessible than Tseung Kwan O. For the index of CTS1, it falls in the second category; i.e. Shatin and Tseung Kwan O have the same accessibility level. For the index of Gutierrez & Gomez, it falls in the third category; i.e. Tseung Kwan O is more accessible than Shatin. This implies that only the measures of Hansen, Ingram, Clark and Martin & Dalvi confirm the hypothesis that “Shatin is more accessible than Tseung Kwan O”.

5.3 Results derived from existing bus routes

For the sake of limited time and resources, only bus routes are analyzed in the study of existing routings of public transits. The choice of bus routes instead of maxicab because it is more popular and it’s carrying capacity is larger than maxicab. Two selected regions in Shatin and Tseung Kwan O are chosen for study. They are the New Town Plaza of Shatin and the Metro City of Tseung Kwan O. These two regions
are in the central locations within Shatin and Tseung Kwan O. Theoretically speaking, centrally located area is relatively more accessible than the rest areas within the same region. When referring to the empirical case, the coverage rate of bus routes for these two areas (New Town Plaza and Metro City) is quite high. There are 14 bus routes from New Town Plaza while 8 routes can be found from Metro City.

5.3.1 Results derived from the existing routes of bus

The results derived from the existing bus routes in the selected regions of Shatin and Tseung Kwan O are shown from Figures 5.7 to 5.12.

Figure 5.7 Accessibility level of Shatin and Tseung Kwan O derived by Hansen’s measure.

Figure 5.8 Accessibility level of Shatin and Tseung Kwan O derived by Ingram’s measure.
Figure 5.9 Accessibility level of Shatin and Tseung Kwan O derived by Clark’s measure.

Figure 5.10 Accessibility level of Shatin and Tseung Kwan O derived by the measure of Martin and Dalvi.

Figure 5.11 Accessibility level of Shatin and Tseung Kwan O derived by the measure of CTS1.
Figure 5.12 Accessibility level of Shatin and Tseung Kwan O derived by the measure of Gutierrez & Gomez.

Figures 5.7, 5.8, 5.9, 5.10, 5.11 and 5.12 show the accessibility level of a selected region within Shatin and Tseung Kwan O for each measure by the mode of bus. It is because only bus is selected as the public transit for the study under this case. With these in mind, the horizontal scale of these figures represent the regions of Shatin and Tseung Kwan O while the vertical scale represents the accessibility level. As mentioned, the regions selected for this study are New Town Plaza of Shatin and Metro City of Tseung Kwan O. So, the x-axis represents these two regions while the y-axis represents the accessibility level of these regions for each of the accessibility measure.

As mentioned in 5.2.1, mean value and standard deviation (s.d.) are used for the comparison of the accessibility level between these two regions. However, only one single regions (New Town Plaza) of Shatin and (Metro City) of Tseung Kwan O are selected for study respectively, no mean value and s.d. can be derived. As a result, comparison of accessibility level between these two regions of each measure is made directly by referring to the figures in concern. The statistical results showing the strength from these two sets of data by using the equation (5.1) is summarized in Table 5.7.
Table 5.7 A table shows the accessibility level of the six measures derived by mode bus.

<table>
<thead>
<tr>
<th></th>
<th>Accessibility level of Shatin</th>
<th>Accessibility level of Tseung Kwan O</th>
<th>Relative difference of the accessibility level (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hansen</td>
<td>1099.079</td>
<td>1099.264</td>
<td>-0.0168</td>
</tr>
<tr>
<td>Ingram</td>
<td>3509.292</td>
<td>1924</td>
<td>45.17</td>
</tr>
<tr>
<td>Clark</td>
<td>3567.121</td>
<td>782.5375</td>
<td>78.06</td>
</tr>
<tr>
<td>Martin &amp; Dalvi</td>
<td>0.995467</td>
<td>0.997511</td>
<td>-0.2049</td>
</tr>
<tr>
<td>CTS1</td>
<td>1.000838</td>
<td>1.000669</td>
<td>0.0169</td>
</tr>
<tr>
<td>Gutierrez &amp; Gomez</td>
<td>12.385</td>
<td>6.7925</td>
<td>45.155</td>
</tr>
</tbody>
</table>

*Relative difference of the accessibility level of Shatin with respect to Tseung Kwan O in %.

When referring to Table 5.7, the measures of Ingram, Clark, CTS1 and Gutierrez & Gomez show that the accessibility level of Shatin is higher than Tseung Kwan O. For the measures of Hansen and Martin & Dalvi, the accessibility level of Tseung Kwan O is higher than Shatin.

As mentioned, only the measures of Hansen, Ingram and Clark show that the higher the accessibility level implies the more accessible the place is, while it is the opposite case for the measure of Martin & Dalvi and Gutierrez & Gomez. The result of the accessibility measures derived from existing bus routes is summarized in Table 5.8.

Table 5.8 The results of accessibility measures derived from existing bus routes.

<table>
<thead>
<tr>
<th>Accessibility Measures</th>
<th>Hansen</th>
<th>Ingram</th>
<th>Clark</th>
<th>Martin &amp; Dalvi</th>
<th>CTS1</th>
<th>Gutierrez &amp; Gomez</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shatin more accessible than Tseung Kwan O</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equally accessible between Shatin and Tseung Kwan O</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Tseung Kwan O more accessible than Shatin</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>

When referring to Table 5.8, only the measures of Ingram, Clark and Martin & Dalvi show that Shatin is more accessible than Tseung Kwan O. Result derived from the
measure of CTS1 show that Shatin and Tseung Kwan O are equally accessible, while for the measure of Gutierrez & Gomez, it shows that Tseung Kwan O is more accessible than Shatin. This implies that only the measures of Ingram, Clark and Martin & Dalvi confirm the hypothesis that “Shatin is more accessible than Tseung Kwan O”.

5.4 Results Comparison

When referring to the summarized result tables of Table 5.6 and Table 5.8 derived from the existing road network and bus routes, only the measures of Ingram, Clark and Martin & Dalvi confirm the hypothesis that Shatin is more accessible than Tseung Kwan O. For the measure of Hansen, it only confirms this hypothesis in the case of existing road network. For the measure of CTS1, it shows that Shatin and Tseung Kwan O are equally accessible in both cases, while for the measure of Gutierrez & Gomez, it shows that Tseung Kwan O is more accessible than Shatin in both cases.

With this in mind, the measures of CTS1 and Gutierrez & Gómez are not recommended for measuring the school trip in Hong Kong. For the measure of Hansen, there is slightly difference between the accessibility level of Shatin and Tseung Kwan O (Table 5.3 & Table 5.7) for both cases. No distinctive differences between two study areas can be shown, so this measure is not under further consideration.

Among the three measures that confirm the hypothesis, the measure of Martin & Dalvi only show a slightly difference of the accessibility level between Shatin and Tseung Kwan O (Table 5.3 & Table 5.7). The conclusion from the empirical test against the hypothesis (5.1.1) reviews that Shatin is more accessible than Tseung Kwan O in a large extent. With this in mind, the measure of Martin & Dalvi is to be considered because it is not applicable for the measuring the school trip in the case of Hong Kong.
With reference to Table 5.3 and Table 5.7, these two measures show that Shatin is more accessible than Tseung Kwan O in a large extent. Based on the conclusion from section 5.1.1, the measures of Ingram and Clark are more applicable in measuring the school trip in the case of Hong Kong.

5.5 Summary

This chapter is the continuation of chapter 4. It concentrates on the results presentation and analysis. Before that, an empirical testing against the hypothesis on Shatin is more accessible than Tseung Kwan O is made in section 5.1.1. This places the criteria for the results presented in the coming sections. Having analyzed the results derived from the case under possible routes and the case of bus routes, it finds that the measures of Ingram and Clark are more applicable for the measuring of school trip in the case of Hong Kong when compared with the rest of the selected measures in this study.
CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

There is a thorough discussion on the background information, how this study is conducted and the conditions are made, and the presentation of the results etc. in the previous chapters. In this chapter, there is a summarization of the main concept of the study. This helps refresh the major concepts made in this study. It includes the background, the work, the findings and its significance. After that, there is a discussion on the potential problems and the limitations. Finally, recommendations are suggested for further studies.

6.1 Summary

Accessibility index is one of the important measures in the field of transportation planning. It is not common for the previous researchers to conduct the study of accessibility by using Geographic Information Systems (GIS). When referring to the objectives in chapter 1, this study has applied the GIS method in the study of the accessibility measures in Hong Kong’s case. This study differs from the previous studies in that it is conducted by using the GIS method. It is rare for the past researchers to conduct the study on accessibility indices on school trip by applying the GIS method. By using the GIS method, more comprehensive study can be conducted. More importantly, it is new to use GIS in measuring the accessibility indices of school trip in the case of Hong Kong.

Shatin and Tseung Kwan O, with different stages of new town development are the regions selected for study. This study is conducted in two perspectives; one is based on the existing road network while another is based on bus routes. Some accessibility indices are selected from the past studies. All of them are under the category of the gravity-type accessibility indices. These indices are the measures of Hansen, Ingram, Clark, Martin & Dalvi, the CTS1 and Gutierrez &Gomez. Some assumptions and a hypothesis are made in order to facilitate the study. It is hypothesized that Shatin,
being an earlier-developed new town, is more accessible than Tseung Kwan O, a recently developed new town, ceteris paribus. This hypothesis has been confirmed by real world data (section 5.1) and a conclusion is drawn. Such conclusion is useful for the determination of the types of accessibility indices which are more applicable for the case of Hong Kong in measuring school trip.

Some common factors can be found among these indices, namely, activity base, travel cost and the calibration parameter. In deriving the value of travel cost, the software ArcView GIS Network Analyst is used. Through a series of trial and error process, the calibration parameter is derived. Having prepared the required elements for the accessibility calculation, the accessibility indices are tested.

Results from both situations show that only the measures of Ingram, Clark and Martin & Dalvi confirm the hypothesis. The conclusion drawn from the empirical test on this hypothesis infers that Shatin is more accessible than Tseung Kwan O to a large extent. Only the measures of Ingram and Clark confirm to this conclusion.

The findings from this study show that the measures of Ingram and Clark are more relevant for the measuring of school trip in the case of Hong Kong.

6.2 Achievements

Studying the accessibility indices by using the GIS method can make the whole study become more quantitative and cost-efficient when complicated process is involved. As the network systems can change over time, a new value of accessibility level can be derived by just updating the GIS database.
6.3 Discussion and Analysis

The summary in section 6.1 only provides a brief review on the major work and findings for this study as a whole. An analysis on the individual finding is discussed in this section.

6.3.1 Derivation of Travel Cost

In this study, travel cost includes travel time cost and travel distance cost. Time cost is derived based on the value of distance and speed. In deriving the distance cost, the locations of origins and destinations are required. The GIS software of ArcView Network Analyst is used to derive the distance cost. As it involves repeated flow from one origin to the rest of the destinations, the Avenue script is used in facilitating the complicated flow. As a result, the results of the distance cost from each origin to the remaining destinations are presented in a table format. The value of time cost can be found when the speed is provided. Hence, both the distance and time cost can be derived. They are useful information for the calculation of the accessibility indices in the section follows.

6.3.2 Derivation of the Calibration Parameter

Apart from travel cost, the value of the calibration parameter is also important for testing the accessibility indices. This is an exponent factor included in various accessibility indices. There is a standardized method derived by Hyman (1969) in deriving this parameter. It involves repeated steps of trial and error. The value of the calibration parameter can be derived through a series of trial and error process. The inclusion of the calibration parameter in the accessibility index can strengthen its representative power to the real world situation. As a result, its role is also important.
6.3.3 Testing Against the Accessibility Indices

Having integrating the required data for creating the database, various accessibility indices are tested. As it involves repeated calculation processes, a calculation program by the language of Visual FoxPro can help. For the measures of Ingram, Clark and Martin & Dalvi, their results show that the students in Shatin are more accessible than those in Tseung Kwan O in both cases. It is the reverse case generated by the measure of Gutierrez & Gomez. The result of the measure of CTS1 shows that the students in both Shatin and Tseung Kwan O have the same level of accessibility. When referring to the conclusion drawn from the empirical study on the hypothesis, it is found that only the measures of Ingram and Clark are more applicable for the measuring of school trip in the case of Hong Kong.

6.3.4 Testing Against the Hypothesis

The hypothesis of this study is that “Shatin, being an earlier-developed new town, is more accessible than Tseung Kwan O, a recently developed new town, ceteris paribus”. As there is a lack of standardized level to judge whether it is really the case or not, real world data is collected to test against it. The numbers of bus and maxicab routings represent the supply side in the transportation market, while the targeted population represents the demand side. In this sense, accessibility level is dependent on the demand for public transits exerted on the existing supply of public transits. A conclusion can be made from the testing against the hypothesis. It concludes that the students in Shatin is more accessible than those in Tseung Kwan O in a large extent. This conclusion is an indicator for the selection of the indices.

6.3.5 Results Analysis

As mentioned, the conclusion drawn from testing against the hypothesis can be an indicator for the results derived from these two cases. Results show that the students in Shatin are more accessible than those in Tsuen Kwan O in a large extent for the
measures of Ingram and Clark. It is only in a small extent for the measure Martin & Dalvi.

6.4 Conclusion

By using the GIS method as the main tool to conduct this study can help handle large amount of data, so a more comprehensive study can be conducted. Through the empirical testing on the cases of existing road network and bus routes, it finds that the measures of Ingram and Clark are more applicable in measuring the school trips for Hong Kong’s case.

6.5 Limitation

Actually, the collection of data is one of the difficult tasks in the process of conducting the study. Especially in the case when this is out of control. For example, the data of the population in Shatin and Tseung Kwan O is from the Census and Population Department of Hong Kong. The data used in this study is the 1996 Population By-census. As all known, the year of conducting the next census is 2001. So, the 1996 Population By-census already is the most updated version at this moment. However, the networking systems, the routings, etc. from the LIC, the KMB Company etc. are in the year of 1999. The three years’ gap in-between can allow steady growth of population in these two regions. So, this provides a dilemma for this study. Besides, there is a lack of data of number of school places and the travelling pattern of school trips from one place to another.

6.6 Recommendation for Further Studies

This study gives insight on the study of accessibility indices in measuring the school trips by applying the GIS techniques. As a result, it finds that two indices among those under study are more applicable in this situation. For further study on the issue
of accessibility measures, the components of the accessibility indices are worth study in detail. This helps strengthen the understanding of the relative importance of each individual component for influencing the value of the accessibility index and the rationale for the inclusion of such factor. Actually, in studying the topic of accessibility in transportation, the factors included in the index like travel cost, calibration parameter and activity base etc. are also important for consideration. They can reflect the main theme of that index. As a result, two indices measuring the same region may have a great difference among themselves because their emphases are different. So, the evaluation of the composition of the accessibility indices not only can help understand the relative importance of each individual factor, but also the implicit meaning of the index itself.
REFERENCES


HKSAR (1999). Transport In Hong Kong. Hong Kong Special Administrative Region Government.


BIBLIOGRAPHY


APPENDIX I
ArcView GIS/Avenue

theView = av.GetProject.FindDoc("Shatin")

'declare the variables for the network
aNetFTab = nil
for each t in theView.GetThemes
   ft = t.GetFTab
   if (NetDef.CanMakeFromFTab(ft)) then
      aNetFTab = ft
      break
   end
end

de we find a networkable FTab?
if (aNetFTab = nil) then
   mbox.Error("Network theme not found. ","
   exit
end

'declare the NetDef and check it for error
aNetDef = NetDef.Make (aNetFTab)
if (aNetDef.HasError) then
   mbox.Error("NetDef has error. ","
   exit
end

'declare the Network object
aNetwork = Network.Make(aNetDef)

'declare the variables for the themes, tables and fields
aPointThemeList = {}
for each t in theView.GetThemes
   if (t.GetFTab.GetSrcName.GetSubName = "Point") then
      aPointThemeList.Add(t)
   end
end

if (aPointThemeList.Count = 0) then
   mbox.Error("No point themes found. ","
   exit
end

origTheme = mbox.Choice(aPointThemeList,
   "Select the origin point theme:",
   "Origin selection")
destTheme = mbox.Choice(aPointThemeList,
   "Select the destination point theme:",
   "Destination (facility) selection")

origFTab = origTheme.GetFTab
destFTab = destTheme.GetFTab

origShapeField = origFTab.FindField("Shape")
destShapeField = destFTab.FindField("Shape")
originLabelField = origFTab.FindField("ID")
destLabelField = destFTab.FindField("ID")

resultVTab = av.GetProject.FindDoc("table1.txt").GetVTab
resultOrigField = resultVTab.FindField("Origin")
resultDestField = resultVTab.FindField("Destination")
resultCostField = resultVTab.FindField("Cost")

'Start the Problem Solving, two "For Loop"
for each i in 0..1
  msgbox.info(i.asstring,"")
  for each j in destFTab
    'return points for origin and destination
    origPt = origFTab.ReturnValue(oriShapeField, i)
    destPt = destFTab.ReturnValue(destShapeField, j)
    'return name of points
    origLabel = origFTab.ReturnValueString(oriLabelField, i)
    destLabel = destFTab.ReturnValueString(destLabelField, j)

    'create the point list to store the origin and destination points
    aPointList = {}
    aPointList.Add(origPt)
    aPointList.Add(destPt)

    'Solve the Network Problem
    travelDistance = aNetwork.FindPath(aPointList, true, false)

    'Set values into the result table
    rec = resultVTab.AddRecord
    resultVTab.SetValue(resultOrigField, rec, origLabel)
    resultVTab.SetValue(resultDestField, rec, destLabel)
    resultVTab.SetValue(resultCostField, rec, travelDistance)
  end
end